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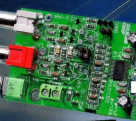

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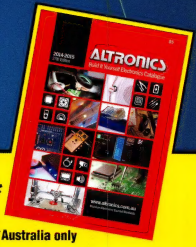

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Ref: Silicon Chip Magazine June 2004

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Ref: Silicon Chip Magazine July 2014

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Ref: Silicon Chip Magazine April 2007

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Ref: Silicon Chip Magazine July 2013

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Ref: Silicon Chip Magazine Mar 2014

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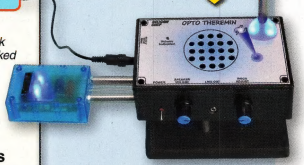

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Publisher's Letter

Debate on the MEN system

Well, well, well. My Publisher's Letter and article on the dangers of Australia's Multiple Earth Neutral (MEN) system in the August issue has certainly triggered a lively discussion, as I thought it might. Some of the ensuing correspondence is featured in the Mailbag pages of this issue. No doubt we will have more next month.

As you would expect, most of the correspondence has come from electricians who are very familiar with the MEN system and wiring practices as specified in the SAA wiring rules (AS/NZS3000:2007). Typically, these tradesmen are conscientious and concerned about any deviation from what they perceive as standard practice. As you will see, some readers were concerned about the standard of wiring shown in the photos of the meter box/switchboard in the article and claimed that it was not "up to scratch".

To be honest, the sight of the bundle of Earth wires behind the hinged-out panel on my switchboard was a surprise to me. If I had thought about it at all, I would have assumed there was an Earth link for all these connections. Prior to taking the photos in the article, I had never looked at it. But I am assured that it does meet the relevant clauses in the wiring rules. If you think about the number of connections necessary for an Earth link bar, it would be quite a long bar and a lot of screw connections, all of which can gradually come loose over time, due to the effects of creepage. So the soldered bundle is probably the better approach for long-term safety.

Other readers were concerned with the fact that I found considerable current flowing in the Earth. Some were adamant that no current at all must flow in the Earth. If you think about it, there must always be some current flowing in the Earth. Consider an installation in which the Neutral circuit back to the power pole is 300 milliohms, a fairly typical value. Now the Earth circuit should also have a very low resistance and what if it, too, is 300 milliohms? This means that regardless of how much current flows in to the Active connection, half flows back to the distribution transformer (or sub-station) via the Neutral and the other half will flow via the Earth.

Other readers maintained that the consumer's Earth should only be a copper-plated stake driven into the ground and no connection to the water pipes. Well good luck with that idea if you live in a hilly area where most of the houses are built on rock. That describes my house and while I do have an Earth stake, it was buried in concrete years ago and even then it must have been in a small pocket of shallow soil over solid sandstone.

And good luck with the idea of keeping the area around the Earth stake well-watered to keep soil conductivity high. How many people even know where their Earth stake is or what it is for, let alone the idea that it should be watered in periods of dry weather? This is why the water pipes become part of the consumer's Earth – it is bound to be a better long-term connection.

And that is the way it has been for a very long time. If not, why are plumbers generally aware of the hazards of removing a water meter? It must be bridged with a heavy jumper lead to provide an alternative path for the Earth currents while the water meter is removed. In that respect, plumbers seem to be more aware than electricians, even though they might not know the reasons why hazardous currents (or voltages) could be present.

Finally, a couple of readers wanted to know if Energy Australia had subsequently made efforts to find out where the apparent Neutral fault in my immediate locality was. The answer to that is "no" and that was the subject of some discussion between the inspector who checked out my installation and his supervisor. The problem is that it could be anywhere or it might be the result of a number of less than optimum consumer Neutral connections, in their switchboard, at the pole or wherever.

Overall, the reaction to the article has been very favourable and everyone agrees that if any person ever gets a tingle from water taps or pipes within their home, they should immediately contact their electricity supplier.

Leo Simpson

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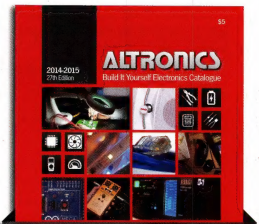

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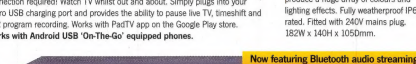

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Valve amplifier has more detailed sound

I read with great interest your project article to build a Nirvana Valve Sound Simulator in the August 2014 issue. Since I rekindled my interest in valve amplifiers nearly 10 years ago, I and my partner are of the opinion that listening to our favourite music through valves is superior.

For many years we have had a reasonably good hifi system, built around solid-state technology. This all began around the 1980s and 1990s when we invested in the following components: Yamaha A960 integrated stereo amplifier, Yamaha CDC 635 5-disc CD player and Monitor Audio MA 100 bookshelf speakers with Monitor Audio WA 200 passive subwoofer. This combination gave us many years of splendid listening pleasure.

Then around 2005, I came back from a trip to Hong Kong, where I purchased a hand-made Class-A valve stereo amplifier. This is based on 300B, 12AU7 and 12AX7 valves, with 5Z4P rectifiers. Upon hook-up at home, using the same speakers and sound source, we were amazed at the additional fine detail in the music, comparing this to what we had been regularly listening to through the Yamaha amplifier (for example, we could now hear the musicians turning music sheet pages in the background). So much so that we preferred to shelve the Yamaha amplifier which is 100W per channel with THD figures of 0.005% whereas the 300B valve amplifier is 10W per channel with harmonic distortion figures of 0.3%.

Then some 12 months ago "The Tube CAD Journal" on the web ran an article on "Restoring Lost Harmonics" – see **www.tubecad.com/2013/06/blog0265.htm**

In the light of your current article on the Nirvana Valve Sound Simulator, I was wondering if you might be interested in seeing this and maybe commenting?

Brian Collath,
Moss Vale, NSW.

Leo Simpson comments: while not denying that your valve amplifier may reveal more detail than the Yamaha, I would want to know precisely why the latter was supposedly so inferior. Possibly, the Yamaha really is inferior, especially at low signal levels where its distortion performance is likely to be nowhere near .005%. After all, it was a 1980s design.

I did look at the article in the "Tube CAD Journal". The idea that you can recover lost detail from a recording by using an amplifier that adds distortion is nonsense. The Nirvana Valve Simulator project is actually an exercise in adding distortion, as noted in the article. It certainly cannot reveal lost detail but it will make a modern semiconductor amplifier sound more like a valve amplifier.

Your Yamaha A960 was a fine looking amplifier. If it belonged to me I would investigate if I could update its electronics with our Ultra-LD Mk3 amplifier circuitry.

Problems with ceiling lights

Most of the ceiling lights in my house are recessed "oyster cans". A few years ago I was alarmed about fires caused by quartz-halogen lamps in ceilings, so I had them changed to compact fluoros (CFLs). Apart from the slow 'warm up', they seemed to be doing the job. More recently, I tried changing to LEDs, with a view to even greater economy, longer life, and less time spent on ladders (one of the commonest causes of injury in older men).

As reported earlier in correspondence to SILICON CHIP (January 2012), LEDs in recessed cans overheated and failed quickly. An editorial note commented that CFLs also require good ventilation and will have a short life in recessed cans. Replacing all oyster

Ground conductivity is important for MEN system

The August Publisher's Letter and the article on the MEN system has reminded me of two situations. First, if the earth connection is solely via an earth stake, the value of the ground conductivity is obviously very important. I have seen an example in which dry weather resulted in very low ground conductivity and effectively no earth. The solution was to water around the ground stake.

The second situation has been seen a few times. Some of the switch-mode power bricks use a 2-pin plug for the power lead. If the Neutral connection is not made and the Active is, a person can receive a mild shock from the low voltage side. This is because there is a small capacitor connecting the primary and secondary sides of the circuitry. The fault only lies partially with the switch-mode design.

The major fault is with the moulding of the plastic around the plug. The Neutral (and Active) brass ring is bonded to the plastic and cannot grip the pin on the power supply.

George Ramsay,
Holland Park, Qld.

Comment: your point about ground conductivity is most important. It is for this reason that the domestic installation should also connect to the home's copper water pipes. Clearly, long periods of very dry weather will prejudice ground conductivity and there can be no reliance on the area around the Earth stake being regularly watered.

cans in my ceiling was going to be a big job, so I went back to CFLs and hoped for the best.

Recently I had to get back up a ladder and replace a CFL. I found blackening due to overheating and started wondering about the next move. A discussion at the American EDN website was very informative, but not very comforting – see www.edn.com/electronics-blogs/led-insights/4423570/That-60W-equivalent-LED--What-you-don-t-know--and-what-no-one-will-tell-you-

Here's what I learned:

(1) The much-vaunted long life-time of LEDs does not apply if they overheat, and overheating is very common.

(2) Recessed fittings are very bad for both CFLs and LEDs.

(3) "Base up" installation for LEDs and compact fluoros is much worse than "base down", and is likely to result in overheating and poor lifetime for both LEDs and CFLs. In my experience this even applies for globes suspended from cords.

(4) The best solution may be track lighting or (although not very practical) long strips of multiple LED chips glued into a U-shaped aluminium channel which acts as a heatsink, so they run very cool and have a long lifetime.

(5) All mains-type LEDs have switching power supplies built into the base of the globe, and these generate electromagnetic 'fog' that can make AM radio reception unusable. Now I know why my AM reception at home is getting worse and worse.

(6) Chinese manufacturers take the view that "as long as the product meets the 'specs' it is OK" while USA engineers talk about "good engineering practice".

We seem to be in a transition phase where the old is out but we don't have generally accepted solutions for the new.

James Goding,
Princes Hill, Vic.

Novel use for old hard disks

Recently, I needed to upgrade my 5-year-old desktop computer and then had to dispose of it. It had a lot of personal data that I really didn't want to be trawled by someone wanting to steal my identity and just dumping it at the local council recycling collection centre didn't appeal. So I removed the old HDD, dissembled it (Philips and flat-bladed screwdrivers were the only tools necessary) to remove the shiny platter itself and I now have an interesting-looking and very shiny coaster for my coffee mug.

My data is secure and probably by now unreadable following spills and scratches. A few weeks later, I did the same for a 90-year old friend who was upgrading from Windows XP. Her HDD was a twin-platter job so she now has a pair of coasters.

Keep up the good work with the magazine.

Jacques Fievez,
East Ivanhoe, Vic.

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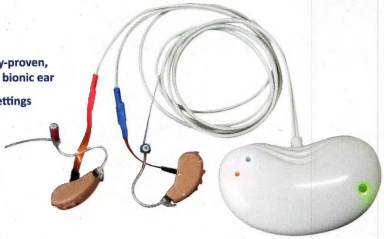

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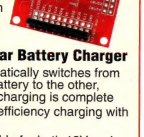

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Mailbag: continued

Majestic speaker system with substitute drivers

I have just built the Majestic Speaker project from your June 2014 issue and it sounds absolutely fantastic. I used separate sheets of timber for the inside box as it was cheaper than buying the Bunnings shelf kit. I also used laminated pine panels for the outside so I could stain it the same colour as the rest of our pine furniture. This also worked out much cheaper than the Kaboodle panels.

As I could not get the Etone horn assembly I decided to do a bit of research and came up with an Eminence PSD2002s-8 HF driver fitted to an Eminence H290s flare. I also used Selenium 15PW3 woofers. All in all, the speaker prices were comparable to the ones that your magazine suggested.

Although I don't have the instruments to measure the performance of the speakers as such, I can tell you that my ears were very pleased with the end result and that's the best measuring instrument of them all. I drive the speakers with a Denon PMA-1060 stereo amplifier. After being in the trade of radio and TV repairs for over 40 years and now retired, I just loved getting my teeth into this project. Many thanks.

Neville Bell.
Wangaratta, Vic.

Comment: you certainly have made a nice job of the cabinets. However, without instruments it is not possible to know just how well your substitute drivers will perform, compared to those specified for the Majestic. The free-air resonance of 37Hz for the Selenium woofer and its much larger Vas figure probably means that it could not achieve the very low bass response that we claimed for the Majestic.

Furthermore, the Eminence compression driver appears to have a significant fall-off in response above 10kHz and this could not be easily fixed by a boost circuit in the crossover network. There also appear to be two tweeter resonances, at 540Hz and 1.8kHz and these may require additional compensation measures. Finally, it's possible that the output from your tweeter needs some tweaking to match that of the woofer.

Having said that, we have no doubt that your speakers do sound impressive.

Misunderstanding of VA and watts

In the letter entitled "Problems With Isolation Transformer Article", SILICON CHIP July 2014, I wish to correct some factual errors in your correspondent's explanation of current with respect to VA and Watts. Your correspondent writes, "For a VA of 920 and a load PF of 0.6, we obtain a power of 522W or a current of 2.27A, not 4A as suggested".

This statement is wrong for the following reasons. VA or volt-amperes is the "apparent power" in the circuit and is derived (as the name implies) by multiplying the circuit voltage directly by the circuit current. This value is independent of the circuit power factor. Thus for a device rated at 920VA operating at 230VAC, the current will be always 4A, irrespective of the power factor.

"True power" is a value derived by combining the voltage and current 'vectorially' where the voltage and current are not 'in phase'. In the case mentioned by your correspondent, the circuit power factor is quoted as 0.6. Since power factor is the mathematical cosine of the angle of lag in an inductive circuit (or lead as in the case of capacitive circuits), the current waveform in this circuit will be lagging the voltage by 53.13° ($\cos^{-1}$ 0.6).

Thus to calculate true power, we multiply 230V by 4A (the result of this is the VA), then multiply by the power factor of 0.6. The result is 552W. Note that the current is still 4A, not the 2.27A he stated.

For a load of 552W to draw 2.27A, the circuit voltage and current would be in phase and the Watts and VA would be equal in value for a circuit power factor of 1, ie, unity.

The fact that the current stays high is the prime reason that power supply authorities insist on high values of consumers' load power factors. The supply authorities must design installations to cope with the values of current as per the apparent power (VA), but consumers only pay for true power (W), since consumers' meters only measure the vectorial combination of currents and voltages no matter how far out of phase they may be.

These quantities may be further explained by the power triangle, where

Beware of Asian wiring conventions

Readers working on imported Asian-manufactured electrical and electronic equipment should be aware of the fact that the wiring colours for these devices can be different to the Australian standard. In these imported devices, Black is sometimes Active and White is Neutral.

While it would be logical to assume that White is Active (as in 3-phase power or twin active for light switches) and Black is Neutral, according to Australian standards, this is not the case with these imported devices.

Anyone changing plugs from 2-pin EU or US to 3-pin AU could easily wire the plugs incorrectly if they are not aware of this wiring convention.

Bruce Pierson,
Dundathu, Qld.

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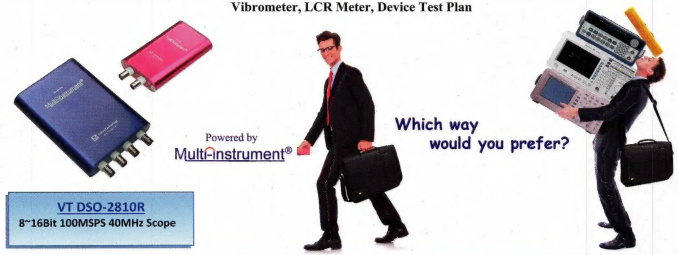

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Mailbag: continued

MEN means 'Multiple Earth Neutral'

My August 2014 copy of SILICON CHIP arrived and as usual I dived into the Publisher's Letter first. Oh dear, Leo, you nearly got my subscription cancelled on the spot. In talking about domestic power supplies, you incorrectly bracketed M.E.N. as "Mains, Earth, Neutral" but all is forgiven, since you got it right in the main article.

I do not know a local 'sparky' with whom I would trust to even discuss your article. I built a new house about 12 years ago and had the wiring done by a 'sparky' I had known for probably 30 or more years at the time. All the cables were run and the sparky himself installed the Earth stake and made the necessary connection, explaining that the water pipes could not be used because (a) they might not be deep enough to get a good earth and (b) there could be (and were) plastic bits.

He didn't know why but that was what the regulations said (I hate regulations which say "do", without an explanation as to "why"). Good, the only thing that concerned me was that in due course I laid concrete paths all around the house meaning that the Earth stake was at least 1.2m from any hope of being watered.

I suppose all is OK since we have since been converted to smart meters. I use the plural deliberately, because I have two of the darn things but that's another story. I assume that if there was a problem the large number of installers who turned up to look at my different system should have spotted any problem.

Graeme Burgin,
Arafat, Vic.

Leo Simpson comments: I obviously had a brain snap when I wrote "Mains Earth Neutral" in the Publisher's Letter. The really annoying aspect is that at least five other people read that editorial and did not see that mistake! Oh, the frustration of it!

I well remember that the editor of another magazine, on being criticised for making a mistake, claimed that he "was only human, after all". I do not make that admission or excuse, even though it might be true!

We have since corrected the error in the on-line edition at: **www.siliconchip.com.au/Issue/2014/August/Electricity+is+a+boon%3b+electricity+is+a+killer!**

Watts lies horizontally at the bottom, VA is the hypotenuse, the Power factor is the cosine of the angle between the two quantities.

Thanks for a great magazine.

Terry Ives,
Penguin, Tasmania.

A climate of chaos?

Has a climate of chaos affected the letters to the Editor? Unless I have been asleep while emailing, I have been wrongly credited with a letter on climate change, on page 10 of the August 2014 issue.

Although I am mainly interested with the other side of the climate/energy debate, from my university lectures on the subject I think the writer was pretty near the mark when he used the word "complex". Perhaps another word that should be added when dealing with the Earth's climate is "chaotic" (as in Chaos Theory?). Even with powerful climate cycles such as the ocean conveyor system, there is so much chaos acting on the global main weather engines; it is a semi-stable system.

Such systems can be provoked into new semi-stable states by short-term external influences. It also does not have to be that powerful (the famous butterfly effect). Just because global temperatures have not risen since 1998 does not mean any extra retained energy from global warming is not affecting other and unobserved susceptible parts of the globe and repercussions arise unexpectedly later.

On the personal observation aspect mentioned in the letter, in 1975 the WA annual rainfall suddenly halved when compared to known records to that date. It has remained so to my knowledge to the present time which

I am sure many older WA residents will attest to. It is a measured fact, which has seriously influenced the fresh water supply situation of Perth. It does not mean by itself that global warming is taking place but does contribute to measured collective knowledge which may indicate a trend to climate change. Personal observations need to be checked against hard data.

Modelling such a system is not for the scientific and maths faint-hearted, as indicated by Dr Bob Lile's letter in the July 2014 issue of Silicon Chip – particularly since the science community in this country is beholden to the politicians for their funding. Politicians are notorious for wanting absolute facts and then tend to shelve facts and the funding for results that are not compliant with their current 'ideology'.

Kelvin Jones,
Kingston, Tasmania.

Comment: we must apologise for wrongly attributing a letter from Alan Wilson, of Glen Iris, Victoria, in the Mailbag pages of the August issue, to Kelvin Jones.

Some electrical wiring practices are dodgy

I have a number of comments regarding the switchboard shown in the article on the Multiple Earth Neutral system in the August 2014 issue.

It is considered good practice for the tunnel screw terminals of earth cables to be double-screw terminal connectors; not single tunnel screw as shown in the picture (people might know them as "blue points"). While it's true that a single screw terminal is permissible, according to AS3000 clause 3.7.2.11 b (ii), many electricians will always use double-screw connectors when connecting earth cables for the reason that unless you have actually measured whether the single screw connector satisfies b (ii) ,you don't know if it meets specifications. With many parts coming from overseas, it would be unwise to simply rely on an assumption that it will be OK to use a single screw connector.

By using a double-screw connector you are assured of a legal connection without any measurement of the connector. I have a suspicion that an old rule in AS3000 said that double-screw connectors were the only ones you could use and this is another reason that the use of double-screw connectors is common in electrical installations, unlike that shown in the pictures of the switchboard. Tunnel screw connectors are also normally very lightly wrapped with some PVC to cover the exposed screw heads. It's considered good practice and this would apply to Earth, Active and Neutral connections.

Another thing I noticed in the picture was the use of a soldered connection of some 15+ Earth cables. Given that all of those cables also seem to be soldered into a small volume, I would have some misgivings about the integrity of the soldered joint if we consider that the combined cross sectional area of that soldered connection would be

Mailbag: continued

Earth stakes can corrode

The Multiple Earth Neutral (M.E.N) article in the August 2014 issue was most interesting. All plumbers should read it.

In the mid-1970s, the earth stake became the mandatory method for earthing electrical installations in all new residential and commercial buildings, alterations, extensions and repairs to existing electrical installations. It's also my understanding that the building earth must have two attachment points – earth stake AND water pipe. These earth connections must also be sprayed with zinc-loaded paint to protect them from the elements and the earth wire itself must face down to minimise water ingress.

The accompanying photos tell the story.

Earth stakes also need replacing; they are a copper-plated mild steel rod. In my case, the earth rod had become a 3-5mm bit of rusted steel after being staked in heavy clay soil for about 30 years.

Cyril Kosorok,
Minchinbury, NSW.

15mm^2 (at the very least) wide and all of those wires would need to be thoroughly heated for a soldered joint to have a good integrity.

Haven't we all had problems when not heating even very small, narrow cables properly and the soldered joint becoming a "dry joint"? You might need a blow torch to heat all those cables in that small volume to the right temperature. The other thing about the soldered Earth connection is that once the whole bundle is soldered together, exactly how would anyone else who comes along actually inspect the connection visually, other than having to physically peel all the PVC tape off the connection?

All things considered, can you see why it is more commonplace to use an appropriate Earth bar that can accommodate a larger number of Earth cables?

Who knows, the bar might even be numbered so that the cables are associated with the Neutral cables leading into the Neutral bar (you are meant to label the protective device, eg circuit breaker with the associated cable on the Neutral bar – CB1 is marked N1

Tenants saved from injury by electrical inspection

The Publisher's Letter in the August 2014 edition of SILICON CHIP should be given wide distribution.

Some years ago, one of my tenants in a Darwin property reported receiving "tingling" when using the taps. I had the matter investigated and it turned out to be the loss of Neutral through corrosion as well as a badly wired hot-water service. I had lived at the property for three years beforehand with my family and without any problems.

The cost of the inspection and repair was a small price to pay to prevent a possible loss of life; not to mention the litigation which would inevitably follow a tragic outcome.

A 'tingle' is a sure sign that more is to come; don't ignore it.

Graeme McKenzie,
Thuringowa, Qld.

to tell you that the associated Neutral of the Active is screwed under number 1).

Using an Earth bar allows easy expansion of the circuit by the next electrician, as they can simply screw down onto a spare terminal (double screw connection). An Earth bar can also be visually and physically inspected by simply testing the screw tightness. AS3000 seems to allow for a bird's nest of Earth cables to be soldered but with some insight into the subject of earthing I myself would not recommend soldered Earth connections in this case. Another thing is that some character might come along, see these soldered connections and then shove the whole thing into a large tunnel screw connection if it were smaller – bad because screwing down onto a soldered joint is considered very bad form, as it creates high resistance joints (I stopped someone from doing it a number of years ago).

Another thing missing from the equation in the picture is a label telling anyone which of those yellow/green cables is the MEN link. According to AS3000, this is now another requirement under the new rules.

On the whole though, the article is very good if an interested party wants to get an idea of how the earthing system really works. It should be required reading for every electrician.

Guy Reece,
Kelso, Qld.

Leo Simpson comments: as far as I know, the switchboard is completely legal, conforms to AS:NZS3000 and has been inspected on at least two occasions. The first was about 15 years ago when I had the house completely rewired, a new switchboard and box installed and new mains out to the pole. At the time I insisted on having a complete inspection. Then, as reported in the August 2014 article, the entire switchboard was thoroughly checked by an Energy Australia inspector. He even checked the tightness of all Earth and Neutral connections. The Earth bundle is soldered and is legal.

However, it does seem as though energy authorities around Australia do maintain different standards. SC

How OMEGA Ruled The World Before GPS

By Dr DAVID MADDISON

Question:
What was the main global real-time radio navigation system before GPS took over in 1997?

If you answered "Omega", you are correct.

And where is the tallest man-made structure in the Southern Hemisphere?

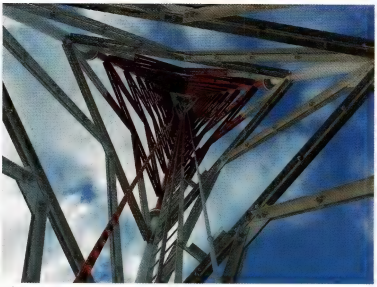
The answer is the now-obsolete 427m high Omega tower near Woodside in Victoria.

Here's how the Omega system worked – and was used for more than 20 years.

Omega is now obsolete but the huge antenna mast still stands as an imposing landmark in the Gippsland area in south-eastern Victoria.

The tower is 427.45 metres high (1,402.4 feet) and when it commenced operation in 1982 it was the fourth highest structure in the world. It is also said to be the world's tallest Very Low Frequency (VLF) radio antenna.

Since the tower is close to the sea, it is used by fishermen as a visual guide to their location. Assuming a 472 metre height (the base of the tower is about 45m above seal level) and a fisherman with his eyes 2 metres above the water, the top (bright red during the day and illuminated at night) can be calculated to be visible from about 83km away.



To get to the top, you have to climb that ladder seen in the foreground – there is no lift or hoist. The person you can (perhaps!) see is an abseiler, probably illegally descending from inside the top of the Woodside Omega Tower. There has also been at least one death amongst daredevils using the tower for illegal BASE jumping. ***Attribution: "Woodside Omega Transmitter" by Nickinator – Own work.***

The tower was originally intended to be built in a more optimal location in New Zealand but this did not happen, because of opposition by protest groups against military infrastructure, even though it could be used by civilians.

There were seven other stations around the world, used in conjunction with the tower in Victoria.

The Omega Navigational System preceded GPS as a global navigation system and operated between 1971 and 1997, transmitting VLF radio signals between 10kHz and 14kHz to provide navigational fixes.

The system was developed by the United States, although a US court subsequently determined that it was based on work by the British Decca Navigator company. It received US Government approval for go-ahead in 1968.

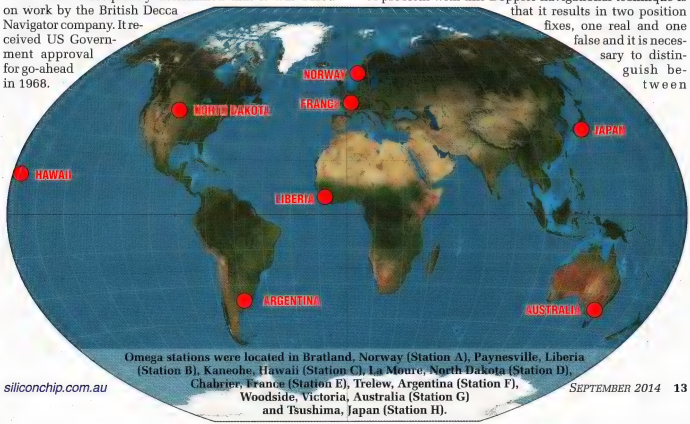
The US Navy had a very specific and specialised need for Omega, apart from it being a general purpose, global, real-time navigation system.

In 1964 it was introducing a fleet of navigation satellites called TRANSIT (also known as NAVSAT – Navy Navigation Satellite System). These would allow global high accuracy position fixes of around 120 metres (decreased to 3m by 1980 with software improvements and better geodesy models) which would originally be used to reset the inertial navigation systems on submarines (later TRANSIT became widely used elsewhere).

Ground stations used the Doppler effect from signals transmitted from these satellites to determine their position much like (but in reverse of) how the Argos satellites (see SILICON CHIP, July 2014) determine the position of some models of the Argo floats.

TRANSIT satellites were in use for more than 30 years, from 1964 to 1996, for both civilian and military use and these seemingly indestructible satellites remain in use today, as part of the US Navy's Ionospheric Monitoring System.

A problem with this Doppler navigational technique is that it results in two position fixes, one real and one false and it is necessary to distinguish between



Omega stations were located in Bratland, Norway (Station A), Paynesville, Liberia (Station B), Kaneohe, Hawaii (Station C), La Moure, North Dakota (Station D), Chabrier, France (Station E), Trelew, Argentina (Station F), Woodside, Victoria, Australia (Station G) and Tsushima, Japan (Station H).

After the Omega System shut down, some of the equipment was transferred to the Maritime Museum in nearby Port Albert (http://yarrampa.customer.netspace.net.au/pamm.html). This is just one of the items on display: an Omega receiver (although there were many types).

the two. Traditional navigation techniques were not always accurate enough to do this but Omega could provide the correct one.

Omega's design accuracy was 2 to 4 nautical miles (3.7 to 7.4km) but this was largely dependent upon the accuracy of tabulated radio propagation predictions.

TRANSIT positions were more accurate than Omega's so they were used but Omega's fix was good enough to distinguish between the real reading and the false one.

And although TRANSIT position fixes were more accurate than Omega's, another problem with TRANSIT was that it took several hours before a fix could be obtained at the equator and one or two hours at mid latitudes. Thus it was not a real-time system, unlike Omega.

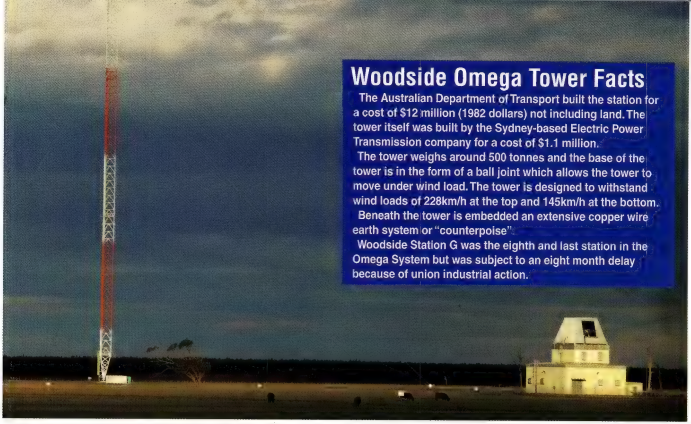
So despite the better positional accuracy available with TRANSIT, Omega soon became an accepted navigation system in its own right.

And before GPS, Omega was *the* state-of-the-art real-time global navigation system. Other navigation systems were available and more accurate but were not global in scope, having only limited range or regions where they could be used.

Very low frequencies

Omega antennas were so large because they operated at very low radio frequencies; from 10 to 14kHz. The wavelength of these frequencies is 21km to 30km so the antennas have to be very large to be even moderately efficient. Even so, they are only a fraction of the wavelength in height. One quarter wavelength would be ideal but a

This Omega Aerial Tuning Relay was one of five units and is shown with cutaway sections. Each of the five relays might switch twice in each ten second cycle to change the frequency of the signal (see table overleaf) meaning that each relay would have to operate around 6,000,000 times per year. The noise of the switching relays could be heard up to 400 metres away, even though housed in a heavily built concrete building. The white objects inside the relay are vacuum switches designed to prevent arcing as voltages as high as 200,000 volts may be present. The vertical copper tubes were designed to prevent electrical losses as AC currents tend to be conducted on the surface (skin effect) rather than deep inside a solid conductor. The donut-shaped rings were designed to prevent corona discharge and arcing as they offered a smooth surface and the black spheres on the right were spark gaps to allow a harmless discharge of any electrical arcing that was to occur.



Woodside Omega Tower Facts

The Australian Department of Transport built the station for a cost of $12 million (1982 dollars) not including land. The tower itself was built by the Sydney-based Electric Power Transmission company for a cost of $1.1 million.

The tower weighs around 500 tonnes and the base of the tower is in the form of a ball joint which allows the tower to move under wind load. The tower is designed to withstand wind loads of 228km/h at the top and 145km/h at the bottom.

Beneath the tower is embedded an extensive copper wire earth system or "counterpoise".

Woodside Station G was the eighth and last station in the Omega System but was subject to an eight month delay because of union industrial action.

quarter wavelength of 10kHz is 7500 metres so the size cannot be anything like that. Because of this the efficiency is very low, perhaps only a few percent .

Due to the low efficiency of VLF antennas a very high input power and drive voltage is required for a much smaller output power, however the output power of this Omega antenna was 10kW, as it was for all other Omega installations around the world.

VLF frequencies were chosen because (a) the VLF signals would be propagated globally with little attenuation in the natural wave-guide created between the earth and the bottom of the ionosphere, which would also minimise the number of stations required, (b) the stability of VLF signals as they are not subject to much fading and (c) the relatively great distances between lines of zero phase difference within which vessels would locate themselves, provided by the long wavelength of the radio waves.

Top guy wires driven elements

In the case of the Victorian installation, the tower itself is not an active antenna element. Instead, the uppermost guy wires are the electrically active elements.

These radiating elements are electrically insulated from both ground and the mast and are arranged in a pattern akin to the ribs of an umbrella.

"Umbrella" antennas radiate vertically polarised waves which is appropriate for the atmospheric wave-guide mode of propagation with wave-fronts oriented vertically between the ground and the bottom of the ionosphere.

Other towers may have had different designs depending upon local circumstances.

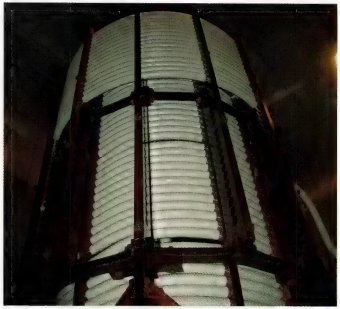
The eight Omega stations were installed around the world, distributed in such a manner that a receiver would be able to receive signals from at least five transmitters. In addition there was a testing station in Forestport, New York.

The Omega system was operated by the United States Coast Guard in partnership with Argentina, Norway, Liberia, France, Japan and Australia.

Conspiracy theories abound

As with most technical subjects that have *any* military connection, conspiracy theories abound regarding the actual use of the Woodside Omega Tower (just as they still abound regarding North West Cape).

And who could forget the crackpot claims which came



This enormous helix coil is part of the matching circuitry in the antenna feed, required because the wavelength of the antenna is very much shorter than even a quarter-wave of the signal wavelength. The gauge of the coil "wire" and the size give some idea of the powers involved. (Photo courtesy Catherine McAloon, ABC Gippsland).

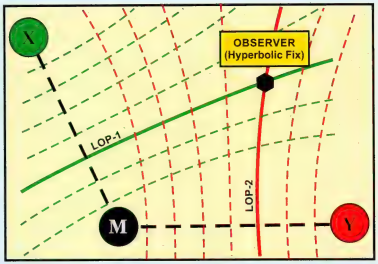
Omega's "Hyperbolic" Navigation System

A hyperbolic navigation system involves measuring the timing or phase difference for the reception of two radio signals from different places to establish the relative distance from each station. One way these timing differences can be determined is through looking at the phase difference between the received signals. If the transmitted signals were perfectly synchronised with each other and if the receiver was equidistant between two stations, there would be zero phase difference between the two signals. If the receiver was closer to one station than the other, there would be a phase difference, indicative of the relative distance to each station.

Plotting on a map the location for all possible positions corresponding to the observed timing or phase differences results in a hyperbolic line called the Line of Position (LOP). The receiver could be anywhere along that line so another measurement is made with a different (third) transmitter. This results in another Line of Position. The point at which these two lines intersect corresponds to the position of the receiver.

The reality is a little more complicated though, as there are multiple points where zero phase difference can occur. As one travels away from a point of zero phase difference going closer to one transmitter and away from the other, the phase difference increases from zero to 360°. A phase difference of 360° is the same as a zero phase difference. The distance between these points of zero phase difference (or zero phase contour lines) correspond to one half of the wavelength of the radio signal.

Since the distance between stations is much greater than half the wavelength of the transmitted signal, there are multiple zero phase contour lines. These zero phase contour lines are known as "lanes" which are shown as the dashed lines on the diagram above



Hyperbolic Lines of Position (solid lines). The dashed green lines show zero phase contour lines between station M and X and the dashed red lines show zero phase contour lines between station M and Y. These dashed lines correspond to "lanes". The Lines of Position (LOP) for the observed timing or phase differences have been plotted by the observer for both stations X and Y and the intersection of these lines gives the position of the vessel.

At the lowest frequency of 10.2kHz used by Omega, the lane width was around 14.7km or 8 nautical miles (corresponding to half the wavelength). Different frequencies resulted in different lane widths and different frequencies could also be combined to generate very wide lane widths for purposes we shall see later.

The position of these lanes was plotted on reference maps. For reference purposes the lane midway between stations was numbered 900 and with the lane numbers decreasing toward the station with the lower letter designation and increasing toward the station with the higher letter designation (eg, decreasing toward Station A and increasing toward Station H).

TRANSMISSION DURATION (s)	0.9	1.0	1.1	1.2	1.1	0.9	1.2	1.0
Station A: Bratland, Norway	10.20	13.60	11.33	------	------	------	------	------
Station B: Paynesville, Liberia	------	10.20	13.60	11.33	------	------	------	------
Station C: Kaneohe, Hawaii	------	------	10.20	13.60	11.33	------	------	------
Station D: LaMoure, ND, USA	------	------	------	10.20	13.60	11.33	------	------
Station E: Chabrier, France	------	------	------	------	10.20	13.60	11.33	------
Station F: Trelew, Argentina	------	------	------	------	------	10.20	13.60	11.33
Station G: Woodside, Vic, Australia	11.33	------	------	------	------	------	10.20	13.60
Station H: Tsushima, Japan	13.60	11.33	------	------	------	------	------	10.20

Each Omega station transmitted three different frequencies in a unique order and duration and could be identified on that basis. For example, Station A transmits 10.2kHz for 0.9 seconds, then 13.6kHz for 1.0 seconds, then 11.33kHz for 1.1 seconds. Between each transmission there is a 0.2 second delay. Note that for any point in the transmission sequence there were always three different frequencies being received, 10.20, 11.33 and 13.66kHz from three different stations. For example, when Station A transmitted its 0.9 second 10.20kHz signal, Station G was transmitting on 11.33kHz and Station H was transmitting on 13.6kHz with a total transmission cycle takes of 10 seconds, endlessly repeated. All stations were synchronised via Caesium beam atomic clocks. Note that throughout Omega's service life some frequencies were changed and also each Omega station transmitted an additional frequency as an aid to identifying the station; not for navigational purposes.

In addition, it was possible to determine the relative position within these lanes by examining the proportion of phase difference corresponding to the relative position within the lane (from zero to 360° representing from zero to 100 percent of the lane width), so the lanes could be further divided into 100 equal parts for greater accuracy.

The big question was, which lane was one within? As it turned out, it was not possible to directly determine what lane one was within. It was necessary to count the lanes a vessel crossed from the time it began

its voyage from the port whose position was accurately known. This lane count was related to a map showing the lanes for a particular geographic area.

A problem arose if the lane count was lost for any reason, such as due to power or equipment failure, adverse radio propagation conditions or transmitter failure. In the event of a loss of lane count it was easy enough to re-determine the position within lanes but the actual lane numbers were not known and had to be determined.

This inability to directly determine a lane number if the initial lane count was lost was known as "lane ambiguity". It was therefore necessary to know one's approximate position using navigation techniques such as maintaining a vessel track with dead reckoning. But the accuracy of the vessel track determined by dead reckoning or other traditional means was less than the spacing of the lanes so it was not possible to accurately locate the vessel within any particular lanes with certainty. In reality, a proper location fix within the lanes required that the other navigation method (eg, dead reckoning) be accurate to half a lane width.

Lane width could be increased by changing the transmitting frequency but 10.2kHz was already the longest wavelength in use and therefore the widest lane width. But as shown in the table at left, there were three transmission frequencies, at 10.20kHz, 11.33kHz and 13.60kHz. The 13.60kHz signal gave a lane width of 11.0km or around 6 nautical miles; unfortunately an even narrower lane width.

But here is the clever part. These frequencies were carefully selected so that four 13.6kHz lanes (4 x 11.0 = 44km) equal the same width as three 10.2kHz lanes (3 x 14.7 = 44km ignoring rounding errors). When these frequencies are electronically subtracted in the Omega Navigation equipment, 13.60 – 10.20 = 3.4kHz, we get a much lower frequency with a correspondingly greater lane width, the half-wavelength of this frequency being 44km, ignoring rounding errors. This is exactly triple the width of the 10.2kHz lanes.

Then to establish lane count it was only necessary to establish one's position by dead reckoning or other means to within half the lane width or 22km instead of around 7.35km, as with the 10.2kHz signal. This is within the capability of dead reckoning and other means. Having established one's position within the 44km wide lane the position within that lane is determined (on a scale of zero to 100 percent of width).

Recalling that this 44km wide lane corresponds to exactly three 10.2kHz lanes it is then possible to establish which of those lanes the vessel is located within by reference to Omega navigational charts. The frequency is reset to 10.2kHz and lane counting can then resume. The 11.33kHz frequency can be utilised in a similar manner and wider lane widths of 133km can be established.

Of course, in matters maritime, the original measurements were in nautical miles.

All Omega readings had to be adjusted according to correction tables which related the propagation of the VLF radio signal in relation to changes in the ionosphere related to time of year, location on the globe, time of day etc. The corrections may change the percent of lane readings and may even change the lane count number.

Above is a Google Earth image of the tower with the ground plane clearly visible, along with the many guy wires.

out about the HAARP research station (see SILICON CHIP, October 2012).

One story about the Tower in particular and Omega in general, which was published back in 1994 in the "Green Left Weekly", had all sorts of claims and 'statistics' (see www.greenleft.org.au/node/7434).

Now, we're not saying we subscribe to *ANY* of the conspiracy theories in that story but "reading between the lines" does give a few more insights, despite its sensationalism and outright bias.

For example, they query the "10kW" radiated power of Omega, maintaining there is also a half-million watt "ground wave" transmitter also associated with the installation. (We believe that the very high input power – perhaps even approaching 500kW – is required because of the very low efficiency of the antenna. But why ruin a good story with facts?).

Omega shutdown

The Omega Navigation System was shut down worldwide at precisely 0300Z on September 30, 1997. All navigation users, having been given appropriate warning, were as-

Visiting the Tower

The Woodside Omega Tower is well worth a visit, particularly if you're in the Gippsland area. To get there, go a short distance to the east of Woodside on the South Gippsland Highway, A440. You can't miss it! It can be seen from the side of the road (make sure you park safely). You can also see it on Google Earth: its specific location is at 38° 28'52" S, 146° 56' 7" E or -38.481111, 146.935278. There is also a YouTube video by the author showing the installation at http://youtu.be/S_T7hd0oXUE

This equipment rack contains the following instruments: 1) a synchronometer, which kept the signal correctly timed with others around the world, deriving its timing pulses from a caesium beam atomic clock; 2) an Omega monitor, receiving signals from a remote site at Blackwarry for self-monitoring purposes; 3) Omega Format Display showing which stations were transmitting and when; 4) Omega Signal Controller – provided computer control of the signal and also monitoring capabilities; 5) Power supply, one of several required to provide voltages of 12, 28 and 11,000 volts DC and 115, 240, 415, 480 and 9,000 volts AC; 6) Frequency Counter to check the signal or do other system checks; 7) Relay Driver to switch high voltage relays; 8) a modem to communicate with the remote monitoring site mentioned in (2); 9) a high voltage relay to switch 100,000 volts for aerial tuning purposes.

sumed to have migrated to GPS by that time.

While GPS has replaced most radio-navigation systems, they were much more difficult to jam by enemy or terrorist activity than is GPS, which is relatively easy to jam. They were also likely to be more resistant to the effects of electromagnetic pulses from nuclear explosions than are satellites.

Today, we take GPS for granted and it is built into numerous devices such as phones, tablet computers, cameras, cars, collars to track pets and other animals and there are even dedicated GPS units! It is highly accurate (typically within 3 metres) and simple to use. In fact, the typical consumer experience goes no further than seeing one's location on a map or planning a trip route. Navigation technology has come a long way in a very short time.

Use by the Royal Australian Navy

After the Woodside Omega station was shut down it was acquired by the Royal Australian Navy (RAN) for use in submarine communications. VLF signals are useful for submarine communications because unlike other radio frequencies, VLF waves penetrate between 10 and 40 metres into seawater. For this purpose the station had to be converted from operation at 13.0kHz to 10-14kHz and other significant equipment changes had to be made to support the 2-channel constant envelope minimum-shift keying (MSK) required for unidirectional submarine communications.

California-based company Hi Q Engineering, who specialise in LF and VLF communications, was contracted to make these changes. Changes included: adding a phase shift network and converting some existing tuning variometers to T-network coils plus adding a capacitor bank, removal of the existing matching transformer and adding another tuning variometer, reducing the inductance of remaining tuning variometers, modifying the main helix and tapping into it with fewer turns, major changes to the helix network; and adding digital antenna current metering and an automatic antenna tuner.

After these modifications the station supported 100 baud two channel MSK transmission with 150kW antenna input power and a radiated power of 36.5kW. Its station designation was VL3DEF.

It was shut down for Navy and all other use on December 31st 2008, as it was no longer considered viable for use.

Incidentally, there is another large VLF transmitter still in use in Australia. The Naval Communication Station Harold E. Holt at North West Cape is a joint facility of the US Navy and RAN. With 13 towers ranging in height from 304 to 387 metres it operates at 19.8kHz, with an input power of around 1MW. A counterpoise comprising a mat of 386 kilometres of copper wire is buried underneath the antenna array.

The Omega tower's future?

The future of the Woodside tower is uncertain, depending on who you ask. Some say it should be removed as even ongoing maintenance is no longer justifiable (there are numerous reports of its aviation hazard lights failing and not being replaced as quickly as they might).

But many others say it represents an important part of Australian and international navigational history.

Let's hope an appropriate alternate use is found for this tower, such as for amateur radio groups or scientific organisations (or even legal BASE jumpers or tourist operators) and it is not demolished just because some bureaucrat deems it convenient, economic or politically correct to do so. SC

Warsaw Radio Mast

While the Woodside Omega Tower remains one of the largest radio masts in existence, it is a pygmy compared to the long-wave AM radio mast which once stood in Warsaw, Poland. This was 646 metres (2,120 feet) tall and was the world's tallest structure until its collapse in August 1991.

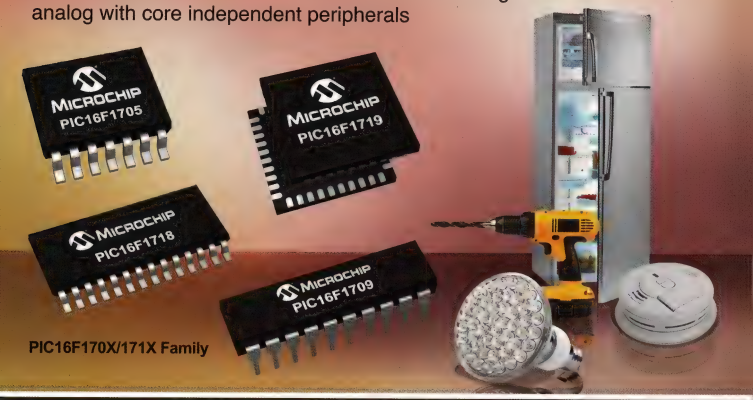
Its two megawatt, 227kHz broadcasts could be heard around the world.

Want to know more?

There's a wealth of information on the 'net – including a US Navy movie on Youtube showing how ships and planes can work out their position and much more. Enter "Omega Navigation" in YouTube's search panel.

Looking to simplify complex embedded control with a cost-effective 8-bit microcontroller?

Microchip PIC16F170X/171X MCUs combine intelligent analog with core independent peripherals

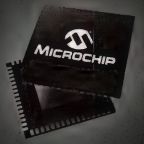


As the first PIC16 microcontrollers (MCUs) to offer Peripheral Pin Select, in addition to Core Independent Peripherals and eXtreme Low Power, the PIC16F170X/171X family of 8-bit microcontrollers offers maximum flexibility and simplicity for embedded control designs.

Microchip's PIC16F170X/171X MCUs bring together intelligent analog functions with Core Independent Peripherals and eXtreme Low Power in a cost-effective 8-bit microcontroller.

The two on-chip op amps can be used to drive analog control loops, sensor amplification and basic signal conditioning, whilst the Core Independent Peripherals enable new levels of performance from an 8-bit architecture.

The core-independent Configurable Logic Cell (CLC) can minimise board space and component count with custom configuration of the logic and interconnects for each design. The PIC16F170X/171X also have on-chip Zero Cross Detect (ZCD) to simplify TRIAC control, synchronized switching control, and timing. The on-chip Complementary Output Generator (COG) provides full/half bridge output control of key parameters such as phase, dead-band, blanking, auto shut-down states, whilst the Numerically Controlled Oscillator (NCO) enables precise linear frequency control with 50% duty cycle or 20-bit general purpose timer/counter.



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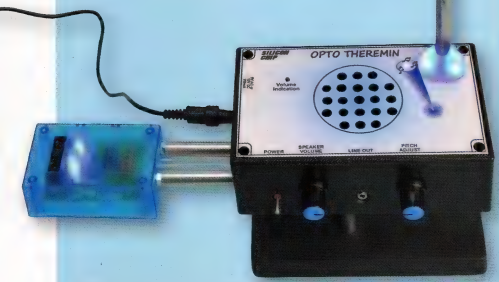
Create eerie musical sounds with the:

Opto-Theremin

Create your own electronically-synthesised music or produce eerie science fiction sounds with our new "Opto-Theremin". This completely new design uses an optical proximity sensor to provide a more effective volume control plate which adds the possibility of rapid tremolo, while vibrato can be applied in the normal way with the vertical pitch antenna.

By JOHN CLARKE



Unlike conventional Theremins, the new Opto-Theremin uses an optical distance sensor to control the volume, making the unit easier to build and adjust. A metal antenna rod is used for pitch control.

THIS LATEST THEREMIN from SILICON CHIP merges the traditional with the modern. As well as the optical proximity control plate, it includes a touch of 'bling' in the form of blue LEDs and polished aluminium tubes. Even the top of the pitch antenna is illuminated with blue light.

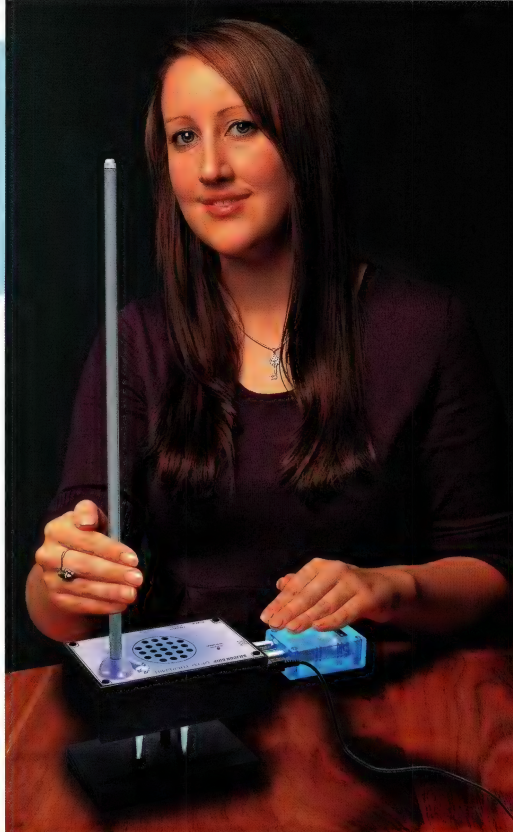
For those who don't know what a Theremin is, it is an electronic musical instrument designed by Leon Theremin in the early 1900s. Pitch and volume are varied by moving your hands near two antennas and a wide range of tones covering several octaves can be produced. Just do a Google search for Theremin to see a selection of YouTube videos of Theremin performances. All of those demonstrations involve Theremins of largely traditional format.

The Theremin owes its popularity to its extreme versatility and to its unique sound compared to conventional instruments. Even a simple combination of hand movements can lead to interesting effects. Theremin passages can comprise a smooth gliding tone (glissandi) or can be separate notes (staccato), or a combination of both. It really is a versatile instrument, limited only by the skill of the player.

Our Opto-Theremin operates in a radically different manner to traditional Theremin designs. The 'Opto' prefix refers to its use of an optical volume control and to the blue LEDs which add visual interest – the 'bling'.

Before anyone starts worrying that our new Opto-Theremin may have lost its heritage, be assured that it sounds just like a traditional Theremin and is played in exactly the same way. For example, the Opto-Theremin still has a vertical antenna for pitch control just

Pt.1



like a traditional Theremin, whereby the right hand is moved horizontally to change pitch.

The big difference compared to a conventional Theremin is the volume control. As with the original, the left hand is moved vertically to control the volume but this movement is sensed using an optical proximity sensor rather than the traditional horizontal loop-shaped antenna.

Why use optical sensing?

This solves a number of problems. Traditional Theremins use RF (radio frequency) oscillators to feed the antennas for both pitch and volume control. Without careful tuning, there can be all sorts of interactions between the volume and pitch oscillators, leading to unwanted 'squawks' in the sound or pitch changes when the player is only trying to adjust the volume.

By using optical sensing for the volume control instead, there's no chance of any interaction with the pitch control circuitry. Additionally, the volume action is always predictable and does not drift with temperature changes. Plus it makes the set-up procedure much easier.

We're still mixing two high-frequency oscillators to produce the audio signal as this results in sounds with the required waveform to imitate musical instruments, such as a cello. So although this new Opto-Theremin has a different method for volume control, it still uses RF techniques to generate the pitch, allowing it to produce the classic Theremin sound.

Features

In order to play a Theremin, the musician must be able to accurately position one hand near the antenna, to produce the required pitch. The generated tone has to be set 'by ear', just as for a violin or a trombone. This is because the Theremin does not have a fixed set of notes but instead delivers a continuous range of tones over several octaves.

Correct linearity of pitch variation in response to hand movement is a critical feature of the design. In this case, 'linearity' means that there is a similar range of hand movement for

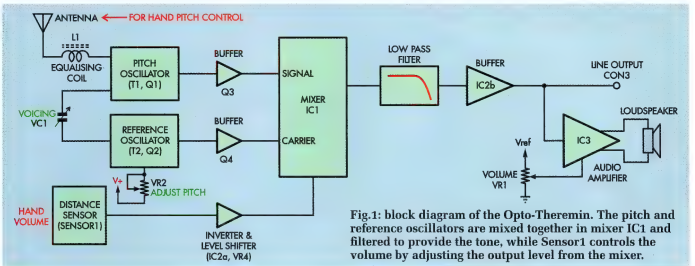


Fig.1: block diagram of the Opto-Theremin. The pitch and reference oscillators are mixed together in mixer IC1 and filtered to provide the tone, while Sensor1 controls the volume by adjusting the output level from the mixer.

each octave. It's important that no octave is compressed into a very small hand movement range, as this would make the instrument difficult to play.

The Opto-Theremin is designed to avoid this and it includes a test circuit to assist in correctly adjusting the linearity. An adjustment is also included to modify the tonal quality or 'voice' of the Opto-Theremin. This allows it to be adjusted from producing a sinusuoidal (or pure) tone through to a sound that's reminiscent of a cello at low frequencies and a soprano voice at higher frequencies. In addition, an externally adjustable pitch control provides compensation for changes in pitch due to the unit's location and its surroundings and/or due to temperature variations.

The unit contains an in-built amplifier and loudspeaker but it also has a "Line Out" socket on the front panel so it can be connected to an external amplifier and loudspeaker system. The loudspeaker volume is independently adjustable so it can be silenced when using an external amplifier or alternatively, used as a monitor speaker during on-stage performances.

Main Features

- External pitch adjustment control
- Linear pitch change with hand movement over four octaves
- Linear volume control with hand movement
- Adjustable hand volume range
- Voicing adjustment (internal)
- Integral loudspeaker with volume control
- Minimal pitch drift during warm-up
- No volume control drift during warm-up
- 9VAC or 12V DC operation @ 250mA (eg, from AC plugpack or 12V battery)
- Line output level: 250mV RMS
- Frequency range: <40Hz to >5kHz

Appearance & controls

As shown in the photos, the SILICON CHIP Opto-Theremin is housed in two plastic cases, one to accommodate the main PCB (and support the pitch antenna) and a smaller one to house the distance sensor PCB for the volume control. They are connected by threaded rods housed within aluminium tubes and the whole assembly mounts on a timber pedestal via another set of aluminium tubes and rods.

The vertical pitch antenna is also made from aluminium tube and is easily detached for transportation. The volume control box is translucent and lights up during operation to make it look 'cool'. A translucent dome at the base of the pitch antenna is also lit using blue LEDs, while a separate blue LED illuminates the transparent cap at the top. These blue LEDs not only give the Opto-Theremin an impressive appearance but also reflect from the player's hands when the instrument is being played, for even greater visual effect.

The three external controls (power, volume and pitch) are arranged along one side of the case, together with the line output socket. Power can come from a 9VAC supply or from a mains-derived 12VDC supply or battery. **Note that a switchmode DC supply (eg, a switchmode DC plugpack) is not suitable for use with the Opto-Theremin.** That's because noise from a switchmode supply would find its way into the two onboard oscillators and upset the operation.

Operating principles

Fig.1 shows the block diagram of the Opto-Theremin. It uses two oscillators: (1) a pitch oscillator and (2) a reference oscillator. Both oscillators are set to run at close to 455kHz. The reference oscillator includes pitch adjustment VR2, to precisely trim the frequency.

While the reference oscillator basically runs at a fixed frequency, the pitch oscillator is varied via the attached antenna. Any hand movement adjacent to the pitch antenna alters its coupling to ground and this changes the frequency of oscillation.

Both oscillator outputs are buffered to isolate them from the following mixer stage, an MC1496 balanced modulator (IC1). As shown, the signals are fed to the SIGNAL and CARRIER inputs of IC1.

Its output comprises several frequencies, including the sum and difference frequencies of the reference and pitch oscillators.

If the two oscillators are almost at the same frequency, eg, 455kHz and 454kHz, then the sum of the two frequencies will be 909kHz while the difference frequency will be 1kHz. The low-pass filter on the mixer's output removes all frequencies above 3.3kHz, leaving only the difference frequency; in this case, 1kHz.

The resulting 1kHz audible tone is then fed to unity gain op amp stage IC2b which buffers it and provides the

line output signal. This also drives a small internal power amplifier (IC3) and loudspeaker.

So far, we haven't mentioned the equalising coil that's connected between the pitch antenna and the pitch oscillator. This vastly improves the linearity of the pitch oscillator's response as it changes frequency due to hand movements near the antenna. Without it, relatively small hand movements would cause large frequency changes at the higher octaves.

The equalising coil works by forming a tuned circuit in conjunction with the capacitance of the antenna. Its resonant frequency is set to just below the pitch oscillator's frequency by its 9mH inductance and the antenna's ~14pF capacitance. Moving a hand closer to the antenna increases this capacitance, thereby reducing L1's resonant frequency.

In practice, changes to the equalising coil's resonant frequency will be much greater than any corresponding frequency changes in the pitch oscillator. This is because hand capacitance effects of just few picofarads will have a far greater effect on the antenna's 14pF capacitance (and hence the resonant frequency of the equalising coil) than on the much larger 220pF capacitor that's in parallel with the 560µH pitch oscillator coil (both contained within a 455kHz IF transformer).

So, with the equalising coil, hand capacitance changes have a greater effect on the pitch oscillator for hand movements further away from the antenna than closer in. This non-linearity counteracts the non-linearity of the pitch oscillator's sensitivity to capacitance changes and results in the required linear response.

For further information on this, see **www.element14.com/community/thread/1802/l/theremin-linearity**

Trimmer capacitor VC1 adjusts the coupling between the pitch and reference oscillators. This is the 'Voicing' adjustment and it affects the waveshape of both oscillators due to intercoupling, thus also affecting the output waveform shape.

In practice, it's just a matter of setting VC1 to obtain the required sound from the Opto-Theremin.

Volume control

As mentioned, we use an optical distance sensor (made by Sharp) for the volume control. It comprises an infrared transmitting LED, a receiving lens and a sensor array. The LED and the receiving lens are spaced about 20mm apart, while the sensor array is a Charge Coupled Device (CCD) consisting of numerous light sensors arranged in a single row.

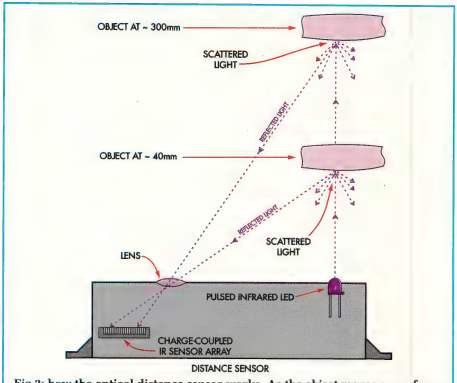


Fig.2: how the optical distance sensor works. As the object moves away from the pulsed infrared LED, the angle of the reflected light passing through the lens changes and this changes the position of the light spot focussed onto a charge-coupled sensor array (or CCD).

In operation, the LED is pulsed so that it produces high-intensity flashes of infrared light focused as a small dot. If an object is within the sensor's range of measurement, the infrared light will be reflected and some of it focused by the lens.

If the reflecting object has an uneven surface, the infrared light will tend to be scattered – see Fig.2. However, part of the light will be reflected back to the lens which then focuses it on the CCD.

The exact position of the light spot on the CCD will depend on several things: (1) the spacing between the IR LED and the lens, (2) the distance between the focal point of the lens and the CCD's light-sensitive surface, and (3) the distance from the reflecting object to the sensor.

The first two distances are fixed by the sensor itself, leaving the distance between the sensor and the reflecting object as the variable.

If the object is close to the sensor, the reflected light will be focussed towards the outside edge of the CCD. However, as the object moves further away, the reflected light angle becomes progressively shallower. As a result, the reflected light progressively moves towards the other end the CCD. The sensor includes circuitry to detect where the light is focussed on the CCD and processes this information to produce a voltage output that varies with distance.

Note that the object does not need to be perfectly flat or parallel to the sensor. The sensor will detect the object as long as there is sufficient scattered light from the object to reach the lens.

Sharp makes several different versions of the distance sensor, each with different optics that set the range of distance measurements. The Opto-Theremin uses the GP2Y0A41SK0F sensor which has a range of 40-300mm. For further information on this device, refer to the data sheet at **www.sharp.co.jp/products/device/doc/opto/gp2y0a41sk_e.pdf**

The output from the distance sensor drives IC2a which inverts and level shifts the signal. IC2a's output then supplies bias current to mixer stage IC1, to control the volume. Inverter

Background To The Theremin

In 1919, Russian Physicist Lev Termen (or Leon Theremin as he is called in the western world) invented an electronic musical instrument called the "Theremin".

At that time, the Theremin was innovative and unique in the musical world and was essentially the first electronic instrument of its kind. Playing it relied solely on hand movements in the vicinity of two antennas to control two electronic oscillators – one antenna to vary the pitch of the sound and the other to change the volume.

The Theremin was subsequently further developed and manufactured by the Radio Corporation of America (RCA) around 1929. General Electric (GE) and Westinghouse also made Theremins in the 1920s. However, the number of units produced was quite modest, totalling about 500.

Today, the Theremin is hailed as the forerunner to modern synthesised music and was instrumental in the development of the famous Moog synthesisers. There is also a website devoted to Theremins (www.thereminworld.com). Because of its unique sound, it has been popular with music producers for both film and live performances. The sound is ideal for setting the scene for supernatural events and for close encounters with extraterrestrial beings in science fiction movies.

A Theremin was used to produce background music in the feature film "The Ten Commandments" by Cecil B DeMille (1956). Its eerie sounds have also made it ideal for science fiction movies such as "The Day the Earth Stood Still" (1951), "Forbidden Planet" (1956) and "Mars Attacks!" (1996).

The Beach Boys also used an instrument similar to the Theremin – called an Electro-Theremin (also named a Tannerin) – in their 1966 hit, "Good Vibrations".

More information on Theremins is available at www.thereminworld.com/Theremin-Models

Finally, SILICON CHIP has produced four previous designs for home construction: a basic Theremin in August 2000, a MIDI Theremin in April/May 2005, the Mini Theremin in July/August 2006 and the Mk2 Theremin in March 2009.

stage IC2a is necessary because the output voltage from the sensor reduces with distance but we want the volume to increase as the hand is moved further away (ie, upwards).

Circuit details

Fig.3 shows the full circuit details of the Opto-Theremin. As well as the distance sensor (SENSOR1), it uses three low-cost ICs (IC1-IC3), four JFETs (Q1-Q4), several coils and sundry other parts.

Both the pitch and reference oscillators utilise pre-wound 455kHz IF (intermediate frequency) transformers (T1 & T2), as commonly used in AM radio tuners. Each of these stages is connected as a common drain Hartley oscillator, with T1 & Q1 forming the pitch oscillator and T2 & Q2 making up the reference oscillator.

T1 has a tapped primary winding with a parallel-connected capacitor to form a tuned circuit. Its resonant frequency can be varied using a ferrite slug which screws into the core. Q1 drives a portion of the tuned circuit winding via the tapping at pin 2, while the signal at the top of the tuned winding is coupled to the self-biased gate of Q1 via a 68pF capacitor. This arrangement provides positive feedback to maintain oscillation at the tuned frequency.

The second winding inside T1, at pins 4 & 6, provides a low-impedance output signal. This signal is fed to the gate of JFET Q3 via a 330pF capacitor. Q3 is wired as a source follower stage, buffering the signal from T1 and feeding it to pin 1 (SIG IN+) of mixer IC1. Current is fed to Q1's drain via a 680Ω resistor connected to the 9V DC supply rail, while Q3's drain current is set by a 100Ω resistor to ground.

The reference oscillator is very similar to the pitch oscillator, the difference being that JFET Q2 is powered via 1kΩ potentiometer VR2 and a 220Ω resistor. VR2 varies Q2's drain-source current to provide pitch adjustment since altering this current affects Q2's gate-source capacitance. This in turn alters the reference oscillator's tuned frequency. Q4 buffers the signal from the reference oscillator, feeding it to pin 8 (CARRIER IN+) of IC1.

Equalising coil L1 is connected directly to pin 1 of T1 by placing jumper link LK1 in its NORMAL position. Moving LK1 to the TEST position means that the equalising coil is in series with a 100kΩ resistor.

Diode D1 connects to the junction of the equalising coil and the 100kΩ resistor, while its cathode goes to test point TP1. In test mode, the equalising coil is sufficiently isolated from the pitch oscillator to allow the resonance of the coil and antenna to be monitored by a DMM set to read DC volts, connected between TP1 & TP GND.

In operation, the DMM filters the rectified RF signal from D1 due to both lead capacitance and internal capacitance, and it discharges this stray capacitance via its own loading. Once the DMM is in place (and LK1 set to TEST), the slug in T1 is adjusted to alter the frequency of the pitch oscillator to give the lowest voltage reading. This sets the pitch oscillator to the resonant frequency of the equalising coil and antenna. The frequency is then adjusted slightly away from this resonance point.

Mixer stage

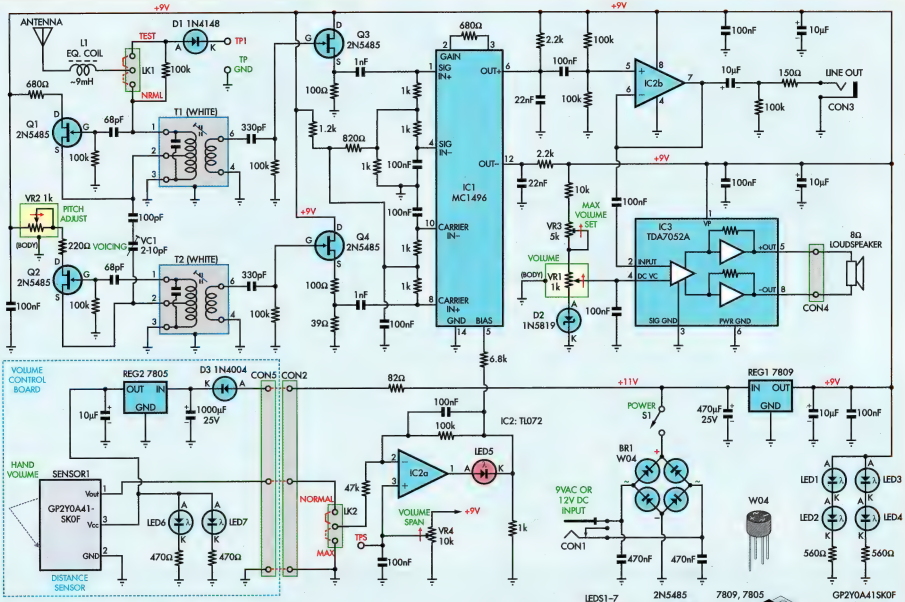
As mentioned, the signals from JFET buffer stages Q3 & Q4 are applied to pins 1 & 8 of mixer IC1 via 1nF capacitors. The signal level applied to pin 1 is around 180mV, while the level applied to the carrier input at pin 8 is reduced to around 50mV by the resistive divider at Q4's source, preventing carrier overload.

The signal inputs at pins 1 & 4 and the carrier inputs at pins 8 & 10 are all DC biased from a voltage divider connected across the 9V supply. This divider comprises the 1.2kΩ, 820Ω and 1kΩ resistors and each input is connect to the divider via a 1kΩ resistor.

Note that the SIG IN- and CARRIER IN- inputs (pins 4 & 10) are only DC biased, with any AC shunted to ground via 100nF capacitors.

The 680Ω resistor between pins 2 & 3 of IC1 sets the gain of the mixer, while the bias voltage applied to pin 5 (from IC2a) sets the signal level at the two output pins (6 & 12). As shown, these outputs are biased using 2.2kΩ pull-up resistors (to the 9V rail) and filtered using 22nF capacitors to remove ultrasonic signals.

Unity gain op amp stage IC2b buffers the low-pass filtered audio signal from pin 6 of IC1. The signal is AC-coupled via a 100nF capacitor to IC2b's non-inverting input (pin 5), while a resis-



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THE OPTO THEREMIN

Fig.3: the complete circuit diagram for the Opto-Theremin. JFET Q1 & transformer T1 form the pitch oscillator, while Q2 & T2 form the reference oscillator. Their outputs are buffered by Q3 & Q4 and mixed in IC1. Pin 6 of IC1 then drives the line output socket via buffer stage IC2b, while IC2b drives audio amplifier stage IC3. Sensor 1 is the optical distance sensor. Its output is buffered and inverted by IC2a which then drives the BIAS input of IC1 to control the volume.

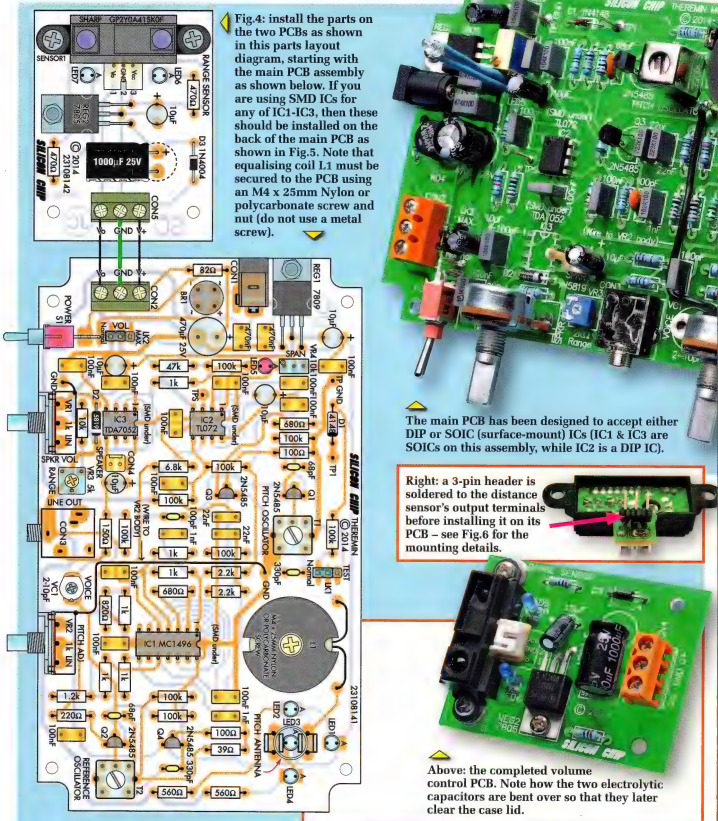


Fig.4: install the parts on the two PCBs as shown in this parts layout diagram, starting with the main PCB assembly as shown below. If you are using SMD ICs for any of IC1-IC3, then these should be installed on the back of the main PCB as shown in Fig.5. Note that equalising coil L1 must be secured to the PCB using an M4 x 25mm Nylon or polycarbonate screw and nut (do not use a metal screw).

The main PCB has been designed to accept either DIP or SOIC (surface-mount) ICs (IC1 & IC3 are SOICs on this assembly, while IC2 is a DIP IC).

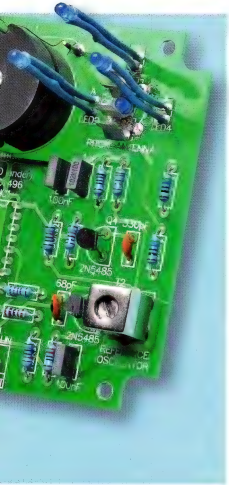
Right: a 3-pin header is soldered to the distance sensor's output terminals before installing it on its PCB – see Fig.6 for the mounting details.

Above: the completed volume control PCB. Note how the two electrolytic capacitors are bent over so that they later clear the case lid.

tive divider consisting of two 100kΩ resistors across the 9V supply biases this input to 4.5V.

IC2b's output appears at pin 7 and is fed to the Line Out socket (CON3) via a 10µF coupling capacitor (to remove the 4.5V DC bias voltage) and a 150Ω resistor. The 150Ω resistor isolates the op amp from any capacitive loads, preventing oscillation.

IC2b's output also feeds power amplifier IC3, a 1W bridge-tied load (BTL) amplifier. Its volume is controlled by a DC voltage at pin 4, with a range of about -70dB to +35dB for 0.4-1.2V.



Volume control pot VR1 is connected in series with trimpot VR3 and a 10kΩ resistor from the 9V supply, with VR1 being the volume control and VR3 being the maximum volume preset.

VR3 allows the top of VR1 to be adjusted from 0.75-1.0V, giving a maximum gain between about -20dB and +20dB. In practice, VR3 is set so that the loudspeaker produces sufficient volume without gross distortion.

The bottom end of VR1 connects to ground via Schottky diode D2. This provides a fixed bias of approximately 0.2V at the bottom of VR1 and is necessary to set the minimum volume level.

Optical volume control

The Sharp GP2Y0A41SK0F distance sensor (SENSOR1) forms the heart of the optical volume control circuit. Its output at pin 1 varies from about 0.4V when the hand is 300mm above the sensor, to about 2.8V at 40mm. The sensor's output is non-linear and must be inverted and level shifted using op amp IC2a to derive the correct volume control function to drive the bias input (pin 5) of mixer stage IC1.

As shown on Fig.3, the sensor's output is fed to the inverting input of IC2a via LK2. IC2a operates with a gain of just over -2, as set by the ratio of the 100kΩ and 47kΩ feedback resistors. IC2a's non-inverting input (pin 3) is biased to about 1.7V by trimpot VR4 and this offsets the output by 1.7V x the non-inverting gain, ie 1.7V x (1+ 100kΩ/47kΩ) = 5.3V. VR4 allows the volume control range to be set to suit the degree of hand movement.

IC2b is configured in a rather unusual way, with its output driving a red (or green) LED (LED5) and a 1kΩ resistor to ground. The arrangement ensures that the output at LED5's cathode can swing all the way down to 0V. This is necessary because IC2a's output can only go down to 1.8V (it's a TL072) and we need 0V to set the minimum bias on pin 5 of IC1.

So why not use an op amp that can swing down to 0V, such as an LMC6482 or LM358? The answer is that these aren't tolerant of RF signals and produced high-frequency noise in this circuit, even with extra compensation and filtering. The TL072 doesn't have this problem. In addition, LED5 acts as a volume indicator, displaying full brightness at maximum volume and dimming down as the volume is reduced.

The output from LED5 drives the bias input of IC1 via a 6.8kΩ resistor. With 0V output, the lack of bias completely shuts down any signal at IC1's output to provide full attenuation.

The maximum output from IC2a is around 7V. So after taking the LED voltage drop into account, the maximum voltage that can be applied to IC1's bias input is about 5.2V, sufficient to give full volume.

Link LK2 is included so that the distance sensor can be bypassed. When it's moved to the MAX position, pin 2 of IC2b inverting amplifier is tied to 0V via a 47kΩ input resistor. As a result, IC2b's output goes high and the distance sensor no longer has any effect, making pitch adjustments easier.

Power supply

As stated, power for the circuit is derived from a 9VAC plugpack or from a 12V DC linear (non-switchmode) supply. RF is filtered from the incoming AC (or DC) rails by 470nF capacitors, while BR1 full-wave rectifies the AC supply. BR1 also makes the unit insensitive to DC polarity. A 470µF capacitor filters the resulting DC, while regulator REG1 provides the 9V rail to power most of the circuit.

A 5V supply rail for the distance sensor is derived via diode D3 and regulator REG2. D3 provides reverse polarity protection, while the following 1000µF filter capacitor is necessary to supply the peak current for the pulsed infrared LED inside the sensor. An 82Ω resistor in series with the 11V supply input limits the peak charging current into the 1000µF capacitor. This prevents unwanted noise in the output due to the pulsing of the IR LED in the sensor.

LEDs 5 & 6 illuminate the area adjacent to the volume sensor with blue light when power is applied. A 470Ω resistor in series with each LED provides current limiting.

Construction

Virtually all the parts for the Opto-Theremin are mounted on the two PCBs. The main PCB (code 23108141) is double-sided and measures 147 x 85mm, while the volume control PCB (code 23108142) is single-sided and measures 61 x 47mm. Fig.4 shows the parts layout for both boards.

Start by assembling the main PCB. This board has been designed to accept either DIP or SOIC (surface-mount) packages for IC1-IC3. DIP package ICs are installed on top of the PCB, while SOIC package ICs go on the underside, as shown on Fig.5.

DIP ICs are somewhat easier to install but many types are now difficult to obtain in this package, especially the MC1496 and TDA7052. An SOIC package is still quite easy to solder though, even though its pins are closer together.

If using one or more SOIC packaged (SMD) ICs, then these should be installed first (see Fig.5). Begin by placing a tiny amount of solder on one of the corner pads, then coat the remaining pads with some no-clean flux paste. That done, place the IC in position (with the correct orientation) and hold it in place using tweezers.

Now solder the relevant corner pin to its pad, then check that the IC is correctly positioned, with all pins centrally located on their pads. If the IC needs adjustment, reheat the soldered pin and slide the IC to its correct position.

Once it's correct, solder the remaining pins but don't worry about solder bridges between pins during this pro-

Parts List

Main Theremin Section

1 double-sided PCB with plated-through holes, code 23108141, 147 x 85mm
1 UB1 plastic utility box, 158 x 95 x 53mm
1 front panel label, 149 x 87mm
1 9VAC 250mA plugpack
1 PCB-mount DC socket (inner diameter to suit plugpack) (CON1)
1 3-way PCB-mount screw terminal block with 5.08mm pin spacing (CON2)
1 PCB-mount 3.5mm stereo switched socket (CON3)
1 2-way polarised header, 2.54mm spacing (CON4)
1 SPDT miniature PCB-mount toggle switch (S1) (eg. Altronics S1498)
1 75mm 8Ω loudspeaker
2 1kΩ linear 16mm potentiometers (VR1,VR2)
2 knobs to suit potentiometers
1 5kΩ horizontal trimpot (VR3)
1 10kΩ multi-turn top adjust trimpot (VR4)
2 2nd IF coils (white) (T1,T2) (can be bought in a set of IF coils from Jaycar Cat LF-1050. Two sets required)
1 potcore pair and bobbin (L1) (Jaycar LF-1060 cores/LF-1062 bobbin, Altronics L 5300 cores/L 5305 bobbin)
2 M205 PCB-mount fuse-clips for antenna connection
1 2-way polarised header plug, 2.54mm spacing, with crimp pins
2 3-pin headers with 2.5mm spacing (LK1,LK2)
2 jumper shunts (for LK1 & LK2)
1 M4 x 25mm Nylon or poly-carbonate screw (to secure L1)
1 M4 x 10mm Nylon or polycarbonate screw (for top of pitch antenna)
2 4mm ID Nylon or polycarbonate washers (spacer for L1)
3 M4 Nylon or polycarbonate nuts (to secure L1 and for top of pitch antenna)
3 M3 x 6mm machine screws
2 M3 x 10mm machine screws
3 M3 nuts
2 M3 x 9mm tapped spacers
1 100mm length of medium duty hookup wire (to earth VR2)
1 200mm length of medium-duty hookup wire or 100mm of light gauge figure-8 wire (for speaker)
1 12m length 0.25mm enamelled copper wire (L1)
1 400mm length of 0.7mm-diameter tinned copper wire (LED lead extensions)
1 400mm length of 1mm-diameter heatshrink tubing (LED1-LED4 leads)
1 10mm length of 20mm-diameter heatshrink tubing (L1)
7 PC stakes (TP, 3 x GND, TP1, TPS, 2 x L1)

Semiconductors

1 MC1496P (DIP) or MC1496D (SOIC) balanced modulator (IC1)
1 TL072CP (DIP) or TL072CD (SOIC) dual op amp (IC2)
1 TDA7052A (DIP) or TDA7052AT (SOIC) BTL amplifier (IC3)
1 7809 3-terminal regulator (REG1)
4 2N5485 N-channel JFETs (preferably from the same manufacturer & batch) (Q1-Q4)
4 3mm blue LEDs (diffused lenses preferable) (LED1-LED4)
1 3mm red or green LED (LED5)
1 W04 bridge rectifier (BR1)
1 1N4148 signal diode (D1)
1 1N5819 Schottky diode (D2)

Capacitors

1 470µF 25V PC electrolytic
4 10µF 16V PC electrolytic
2 470nF MKT
12 100nF MKT
2 22nF MKT
2 1nF MKT
2 330pF NP0 ceramic
1 100pF NP0 ceramic
2 68pF NP0 ceramic
1 2-10pF trimmer capacitor (VC1)

Resistors (0.25W, 1%)

9 100kΩ	2 680Ω
1 47kΩ	2 560Ω
1 10kΩ	1 220Ω
1 6.8kΩ	1 150Ω
2 2.2kΩ	2 100Ω
1 1.2kΩ	1 82Ω
6 1kΩ	1 39Ω
1 820Ω	

Volume Control Board

1 single-sided PCB, code 23108142, 61 x 47mm
1 UB5 translucent blue plastic utility box, 83 x 54 x 31mm
1 Sharp GP2Y0A41SK0F 40-300mm distance measuring sensor (SENSOR1) (RS Components Cat 666-6568P, Littlebird Electronics DF-SEN-0143, Digi-Key 425-2819-ND)
1 3-way PCB-mount screw terminal block, 5.08mm spacing (CON5)
1 3-pin header with 2.5mm spacing (for Sharp sensor)
1 M3 x 6mm machine screw
2 M3 x 10mm machine screws
3 M3 nuts
4 3mm ID washers
1 50mm length of 1mm clear heatshrink tubing (central wire between CON2,CON5)
1 300mm length of 1mm straight steel or aluminium wire (between CON2 & CON5)
1 120mm length of 6mm diameter heatshrink tubing (packing inside aluminium tubing)

Semiconductors

1 7805 3-terminal regulator (REG2)
1 1N4004 1A diode (D3)
2 3mm blue LEDs (diffused lenses preferable) (LED6,LED7)

Capacitors

1 1000µF 25V PC electrolytic
1 10µF 16V PC electrolytic

Resistors

2 470Ω 0.25W 1%

Extra hardware

1 800mm length of 10mm-diameter (OD) x 1mm-thick aluminium tubing (cut for 450mm antenna, volume control attachment and tripod stand)
1 350mm length of M5 or 3/16-inch zinc-plated threaded steel rod (cut to 2 x 62mm and 3 x 75mm)
10 M5 or 3/16-inch nuts to suit threaded rod (eg, Nylon lock nuts in preference to half nuts)
1 151 x 90 x 19mm DAR pine timber
1 29mm-OD frosted half-hemisphere hollow plastic ball (cut from ball salvaged from roll-on deodorant) (optional)

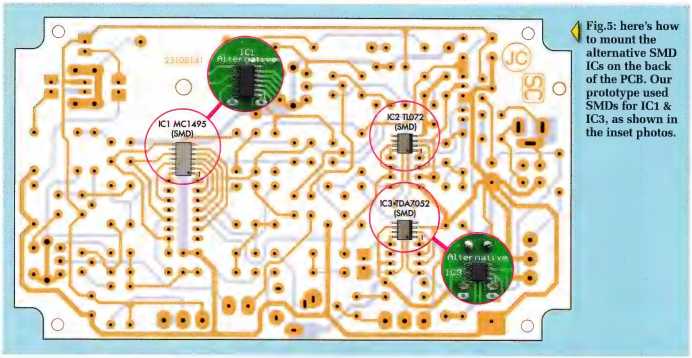


Fig.5: here's how to mount the alternative SMD ICs on the back of the PCB. Our prototype used SMDs for IC1 & IC3, as shown in the inset photos.

cedure. Once all the pins have been soldered, you can remove any excess solder using solder wick.

If you're not using SOIC ICs, or once you've finished fitting them, install the resistors. Be sure to push them all the way down so that they sit flush against the PCB before soldering their leads. Table 1 shows the resistor colour codes but you should also check each one using a DMM before soldering it in position.

Next, fit any DIP ICs, either by soldering them directly to the PCB or using IC sockets. That done, fit PC stakes to the three GND positions (ie, TP GND and the GND pads adjacent VR1 and T1), then TP1, TP5 (adjacent IC2) and for the two wiring points for coil L1. The two 3-way pin headers for LK1 and LK2 can then go in.

Diodes D1 and D2 are next on the list, taking care to ensure that they are correctly orientated. Bridge rectifier BR1 can also be installed at this stage, with its '+' pin positioned as shown.

Follow with JFETs Q1-Q4 and trimpots VR3 and VR4. Note that VR4 is orientated with its adjustment screw adjacent to LED5. The capacitors can then all go in but be sure to orientate the electrolytic types correctly. Table 2 shows the codes used on the low-value capacitors.

LED3 is installed next and must be pushed all the way down onto the PCB before being soldered. Its anode (A) lead is orientated as shown.

Once it's in, the two adjacent M205 fuse clips (used to connect the antenna) can go in. These must have their end-stop tabs broken off before installation, by bending them back and forth using small pliers.

These fuse clips are both mounted slightly proud of the PCB and their pins soldered on both sides of the board, to make a secure mounting receptacle for the antenna. **Do not push the fuse clips all the way down onto the PCB as they could short to LED3's pads.**

The two oscillator coils, T1 & T2, can now be installed. These are both white-cored IF transformers and only go in one way, since they have three pins on one side and two on the other. Push them all the way down onto the PCB before soldering their pins and don't forget to solder the mounting pins on either side of the metal cans.

Once these parts are in, install switch S1, power socket CON1, 3-way screw terminal block CON2 and 3.5mm jack socket CON3. Note that the wire entry side for CON2 must go towards the adjacent edge of the PCB.

9V regulator

Regulator REG1 mounts horizontally, with its leads bent by 90° so that they go through the PCB holes. Secure its tab to the PCB using an M3 x 6mm screw and M3 nut before soldering the leads. Don't solder the leads first; if you do, the PCB tracks could crack as the screw is tightened.

Next, cut the shafts of VR1 & VR2 to suit the knobs that will be used and clean up the ends with a file. That done, snap off the small lug next to the threaded shaft bushing on each pot and install the two pots on the PCB.

The metal body of each potentiometer must be earthed to the PCB via a GND PC stake. For VR1, the GND stake is immediately adjacent and the pot's metal body is connected to it using a short length of tinned copper wire. Note that it will be necessary to scrape or file away a small section of the passivation layer on the pot's body to allow the solder to adhere.

By contrast, VR2's GND stake is some distance away, to the left of coil L1. It should be connected using medium-duty hookup wire. This earth position was necessary to remove background hiss from the Opto-Theremin's audio outputs.

Front-panel LEDs

The remaining LEDs (LED1, LED2, LED4 & LED5) must all be mounted on 35mm lead lengths, so that they later protrude through the lid of the box. This means that you will have to extend their leads using short lengths of tinned copper wire.

Keep the anode leads slightly longer than the cathode leads, to make it easy to check the polarity when the LEDs are installed. It will be necessary to sleeve at least one lead of each LED

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	9	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	1	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	2	2.2kΩ	red red red brown	red red black brown brown
❑	1	1.2kΩ	brown red red brown	brown red black brown brown
❑	6	1kΩ	brown black red brown	brown black black brown brown
❑	1	820Ω	grey red brown brown	grey red black black brown
❑	2	680Ω	blue grey brown brown	blue grey black black brown
❑	2	560Ω	green blue brown brown	green blue black black brown
❑	1	220Ω	red red brown brown	red red black black brown
❑	1	150Ω	brown green brown brown	brown green black black brown
❑	2	100Ω	brown black brown brown	brown black black black brown
❑	1	82Ω	grey red black brown	grey red black gold brown
❑	1	39Ω	orange white black brown	orange white black gold brown

Fig.6: this diagram shows the mounting details for the Sharp optical distance sensor. Note the 3mm stacked washers used as spacers.

Table 2: Capacitor Codes

Value	μF Value	IEC Code	EIA Code
470nF	0.47μF	470n	474
100nF	0.1μF	100n	104
22nF	0.022μF	22n	223
1nF	0.001μF	1n	102
330pF	NA	330p	331
100pF	NA	100p	101
68pF	NA	68p	68

with heatshrink tubing after attaching the wire extensions, to prevent them from shorting.

Once the extensions are in place, mount the LEDs on the PCB (red for LED5, blue for the others), taking care to ensure that they are orientated correctly. It's a good idea to slide a 35mm-wide strip of cardboard between the leads of each LED when mounting it in position. It's then just a matter of pushing it down onto this spacer before soldering its leads.

Equalising coil

Equalising coil L1 consists of a bobbin and two ferrite core halves. The first step is to jumble-wind (ie, randomly wind) 260 turns of 0.25mm enamelled copper wire onto the bobbin. When the winding is complete, lightly twist the two free ends together for about 2mm to prevent the winding from unravelling, then cut the leads to 20mm and scrape away the insulation from each end.

Next, cover the winding with a layer of insulation tape. Alternatively, shrink some 20mm-diameter heatshrink tubing around the bobbin. The coil can now be assembled onto the PCB, as follows:

(1) Position one ferrite core section on the PCB and fit the bobbin in place.

(2) Slide two 4mm-ID Nylon or polycarbonate washers inside the bobbin, so that they rest on top of the inner part of the bottom core (these are needed to provide a 2.5mm spacing between the two cores).

(3) Place the top core in position and secure the entire assembly to the PCB using an M4 x 25mm Nylon or polycarbonate screw and an M4 nut. Be sure to orientate the coil as shown on the parts layout diagram (Fig.4).

(4) Solder the coil wires to the adjacent PC stakes.

Volume control PCB

That completes the main PCB assembly – now for the volume control board. Start by installing the two 470Ω resistors and diode D3, then fit regulator REG2. As before, be sure to secure the regulator's tab to the PCB using an M3 x 6mm screw and M3 nut before soldering the leads

Next, fit the 10μF and 1000μF electrolytic capacitors. As shown, the latter must be installed with its body lying horizontally and its leads bent down through 90° to go through its solder pads. The 10μF capacitor will also need to be bent over slightly so that it later clears the case lid.

The two blue LEDs can go in next. These are mounted with their bodies close to the PCB and are bent slightly towards the 470Ω resistor, so they do not later directly shine into the player's eyes. If you are not using a translucent case, then the LEDs will need to be mounted about 10mm proud of the PCB, so they later protrude through the case.

The distance sensor is installed by first soldering a 3-way pin header to the pins of the right-angle 3-way connector on the underside of its PCB. This is clearly shown in one of the accompanying photos. The sensor is then mounted on the volume control PCB and secured using M3 x 10mm screws and nuts, with two stacked M3 washers serving as spacers on each side – see Fig.6.

Tighten the screws down firmly before soldering the 3-way pin header to the PCB.

That's all we have space for this month. Next month, we'll describe how the two boards are assembled into their boxes, give the final mechanical assembly details and detail the simple test and adjustment procedure. SC

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New Bluetooth Hearing Aid Programmer

Blamey & Saunders' latest programmer for their already amazing value hearing aids makes them even better!

by **ROSS TESTER**

Regular Silicon Chip readers will recall two reviews of new Hearing Aids from Australian company, Blamey & Saunders. We originally purchased some hearing aids back in 2011 and couldn't quite believe the difference they made to a severe case of industrial deafness which occurred some 30+ years earlier ('Australia Hears – and So Do I!' – July 2011).

Later, we had the opportunity to trial some of their new digital hearing aids and found they were even better, even if more expensive. (Silicon Chip, March 2013).

While a little outside the normal 'fare' you might expect to see in an electronics magazine, feedback from readers has been most enthusiastic and quite a few have told us that as a result of those articles, their new Blamey and Saunders hearing aids have "cured" hearing problems they have had for years.

There were two major points of difference between the B&S hearing aids and others we had considered in the past:

(1) They were *significantly* cheaper than the vast majority of "fair dinkum" hearing aids on the market. (There are some el-cheapo units available on the internet – and they are very cheap – but that old adage really does apply here: you gets what you pays for!)

However, despite the B&S hearing aids being around half the price of most quality hearing aids on the market, in this case half price does not equate to half quality. We reckon they're better!

(2) You can program these hearing aids to suit your requirements – so you don't need to spend money to visit an audiologist to have hearing aids programmed – or "tailored" to suit your particular loss. No two cases are the same; in fact it's highly likely that one of your ears has different characteristics to the other, so the ability of being able to individually program your B&S hearing aids yourself is a real boon.

Of course, if you have visited an audiologist and have a copy of your audiogram (ask for it!) then B&S will supply your hearing aids programmed with that data. Incidentally, there are quite a few websites which will also provide you with something of an audiogram – perhaps not up to "professional" audiologist standards, but a good starting point nevertheless.

Assuming you've managed to make the Bluetooth connection (!) programming the hearing aids is so simple, even an octogenarian could do it! Choose the hearing aid type . . .

. . . then it's simply a matter of adjusting the slider bars to suit your particular requirements and save the profile. You can play around without the risk of damaging anything.

But using the hearing aid programmer from Blamey and Saunders, you can build several individual programs within your hearing aids to suit various situations without any professional intervention at all.

New Programmer

Recently, Blamey & Saunders introduced a new, improved programmer. The Incus programmer, in conjunction with their 'IhearYou" software, is both similar and quite different to the old (AHPro3) model – it's similar in the way it works but it is even easier to use. The biggest difference is that it operates via a Bluetooth connection, so it doesn't even need to be wired to the computer.

I'll be honest, at first I had no joy whatsoever in connecting it. After a judicious amount of weeping and wailing etc, this turned out to be a faulty Bluetooth dongle – as soon as I swapped to a laptop with inbuilt Bluetooth and downloaded the new programming software, it connected and worked exactly as it should. Later, I went back to the original notebook PC with a different Bluetooth dongle attached and presto! away it went.

The software is particularly intuitive – you don't really need to have any computer knowledge to run both the software and programmer.

Connecting to the hearing aids themselves for the first time is a little problematic – there is a "shiny" and a "dull" side on the connector which is a little difficult to pick unless you're in pretty bright light. But once connected, it's all child's play (or in my case, senior's play!). You simply work your way through the menu items, adjusting levels to suit your hearing level.

Following my 'road test' of the programmer, I was talking to Blamey & Saunders about my Bluetooth problems and then the success I had.

I mentioned that the one bugbear I had with my new program was the traffic indicators on my new car were so damned loud – really annoyingly so. Their response: "Why don't you create a new program for the hearing aids – call it 'car' – and reduce the levels at those frequencies?" Well, durrr – why is the answer so blindingly obvious you can't see it?

So I did. And the solution was perfect – when I get into the car, I switch over to program 2 (a push-button on these aids) and the problem ceases to exist.

If you have more than one problem (eg, the TV sound must be up too high or you can't understand people in a crowd) you can create separate hearing aid programs to suit those situations.

There's not much more I can say about the new programmer, except that it works! The kidney-shaped device is about 75 x 50 x 20mm so it's smaller than the old one and operates from a single AAA cell. Battery life is about three hours. (That's where I thought the problem was initially – but no, it was the Bluetooth link). Typical of Bluetooth, it will operate up to 10m from your computer and a (new, improved!) Bluetooth dongle is included with the Incus programmer.

On the top side are three LEDs – red and blue show you when the right and left (respectively) hearing aids are connected, while on the right side is a green LED which is inside the (fiendishly cleverly disguised!) power button.

This Incus/IHearYou package normally sells for $295 but is included with new hearing aid purchases from Blamey and Saunders. The software includes lifetime updates and support.

Blamey & Saunders Hearing is based in Melbourne (364 Albert St, East Melbourne, Vic 3002) but operates Australia (and world) wide via the 'net. For more information and a free on-line hearing test, visit **www.blameysaunders.com.au** or call them on (03) 9008 6371. SC

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SERVICEMAN'S LOG

Cameras can be tricky to repair

Dave Thompson*

Many people think that there isn't a lot inside a camera. However, there's a surprising amount of electronic jiggery-pokery lurking inside even the most basic unit. And as with other electronic devices, things can and often do go wrong but fixing them requires the skill of a brain surgeon.

Items Covered This Month

- Cameras can be tricky to repair
- The snake in the air-conditioner
- Beyonwiz PVR repairs

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Cameras can be awkward devices for a serviceman to repair, mainly because there are so many different types. There are also lots of different systems used and this makes them particularly challenging, especially for a novice. Just pulling them to bits can be a lesson in frustration and a test of dexterity and skill.

For starters, cameras contain electro-mechanical systems to control or adjust (among other things) focal length, shutter speed, exposure, white balance, zoom and flash intensity. Some even include circuitry to make fake shutter sounds. But it doesn't stop there; just about every function on a modern camera is electronically controlled or guided using a complex arrangement of electric motors, sensors, switches, displays and other components.

In my opinion, some modern cameras, especially state-of-the-art, top-of-the-range models, are more sophisticated than just about any other consumer electronic device. And they not only boast all this wizardry but it's also packed into the tiniest of spaces.

I clearly recall the first camera I opened up many years ago. It was a Yashica FX-D SLR camera (purchased from my brother) and I couldn't believe the places they'd managed to cram circuit boards bristling with transistors and ICs. And that was long before the advent of microscopic, surface-mount components. That old Yashica was my introduction to camera repairs and though I've not seen many others of this type since then, the lessons I learned were well worthwhile.

The first thing I learned was that it is imperative to have the right tools for the job. A set of Fathers' Day screwdrivers, a hammer and a set square are not going to help you disassemble a camera body. Many cameras are held together with a weird and wonderful assortment of clips, safety screws and other fasteners, and some of them require specific driver bits to undo.

In short, the old trick of using a small, flat-bladed jewellers' screwdriver to see if you can fluke undoing a 'weird-headed' screw usually doesn't work. Instead, you'll likely end up wrecking both the screw and the screwdriver blade and trying to drill out damaged screws from a $1000 camera body is not something I want to experience.

Another essential item is one of those fabric aprons watchmakers and jewellers use to tuck into the workbench when seated. These catch anything you drop and my trick is to use a makeshift apron fashioned from an old sheet. It may look a bit naff but believe me, grubbing around the floor looking for a screw the size of a pinhead looks a lot less dignified. And if your workshop floor is anything like mine, chances are you'll never find what you are looking for anyway.

An apron like this can also save the day if you drop something breakable – the falling item simply lands in the apron like a trapeze artist falling into a safety net. Again, this is preferable to it hitting the floor; lenses and filters especially don't like the sudden stop at the bottom.

So the right tools are essential. But that will get only you half-way to completing the job; technical ability, skill and luck are necessary to complete the other half.

Even so, unless one is used to repairing cameras, they can be intimidating devices. Part of the problem is that if a circuit board is dead, then unless you have a circuit diagram and you're good at working with surface-mount components on tiny PCBs, the repair involves replacing the entire module. Getting replacement parts for many cameras can be difficult however, especially older models. What isn't available new may have to be scavenged from salvaged units at a repair shop but either way, they'll probably be quite expensive.

In short, whatever it is that's killing your camera, you'd better hope that it's something that doesn't involve swapping out major parts.

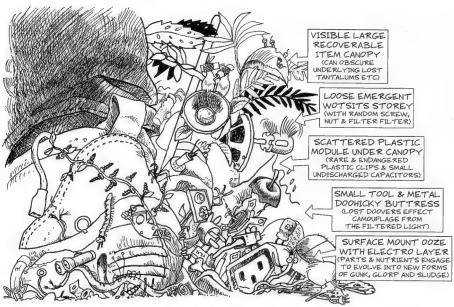
As mentioned, my first camera repair job involved my Yashica FX-

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.



CHARTING THE SERVICEMAN'S FLOOR

D, a highly-regarded unit in its day. Unfortunately, I'd managed to drop it while taking photos of anything and everything, as you do when you first get a new camera. That was in the days when photos were on film and you typically had 12 or 24 shots before having to change the roll. Not only that, once you'd taken the photos, you then had to take the roll to an agency to have it developed and the photos printed. All this cost about the same as a small house, so you very quickly learned to ask yourself "do I really need to take this photo?"

The accident itself was simply due to carelessness on my part. I'd put the camera up on a shelf about 2m high for safe keeping and turned to walk away. Unfortunately, as I did so, the padded shoulder strap I'd added that very day caught my wrist and the following few seconds played out in slow-motion. I'd swear I had time to stroll back and catch the camera but in reality, I stood transfixed and could only watch helplessly as it fell all the way to the carpeted floor.

I couldn't believe it; I'd owned this expensive camera barely 72 hours and it was probably already ruined. I gingerly picked it up and turned it on and was relieved to hear the camera come to life. A quick look through the viewfinder revealed no broken lenses, mirrors or other optics, so I took a quick test photo and all seemed OK except for one problem – a small spot had appeared in the field of view. It wasn't on the lens or on the outside of the viewfinder, so it had to be inside somewhere.

Now being an 18-year-old, second-year avionics apprentice flush with newly-acquired technical skills, I thought that I was able to repair anything. As a result, I quickly developed a burning need to pull the camera apart to see what that the spot was and to determine if it was an indicator that something had broken. And so my first foray into camera repair was to check out and hopefully remove the only visible consequence of that fall, the spot that appeared in the viewfinder.

I'd already determined that whatever was causing the spot wasn't on the outside of the optics. The lens was connected to the camera with a bayonet-style fitting and a quick twist soon had it off the body. I immediately took a good look through it but that didn't reveal anything either.

Just to be sure, I gave everything a quick going over with a lens-cleaning wipe but the spot remained. So whatever the foreign object was, it was definitely somewhere inside the camera body and that meant taking it apart. At that stage of my engineering career, I would happily (and yes, recklessly) open up anything without fear of not being able to put it back together again. What's more, I had by then acquired an awesome set of very high-quality tools, including some pretty cool instrument repair hardware (most of which I still have). I also had access to some of the most advanced workshop equipment available anywhere at the time (and some serious engineering talent to go with it should I come unglued), so I was confident that fixing my camera wouldn't be a problem.

At the time, it was quite acceptable at the airline's workshops to work on 'foreign orders' in our spare time. These were mainly jobs that we brought in from home and so, one lunchtime, I set about disassembling the camera with the intention of locating and (hopefully) resolving the problem.

The first thing I noticed was just how small and fine everything was, so I had to utilise a desktop magnifier almost from the beginning. Fortunately, the workshop I was seconded to as part of my apprenticeship had high-quality, back-lit magnifiers fitted to most of the workbenches so I was in business.

Well, almost – there was no YouTube, Google or even a publicly-accessible Internet in those days, so searching for a 'walkthrough' on disassembling and repairing a Yashica FX-D wasn't even a distant dream back then. With no information to hand, I was going to have to wing it and rely on the experience of those around me if things turned sour.

This camera was very well-engineered and there are similarities with the way Apple products are now put together. Where a sturdy plastic clip would suffice to hold something in place, one or more tiny screws are used instead. But while these products are undoubtedly well-made, they can also sometimes be over-engineered. It can be a servicing nightmare when it comes to remembering where each screw goes and while some manufacturers use the same-size tiny screws throughout their devices, many do not. As a result, the average serviceman ends up with a parts bin full of many different types of screws and has the enviable task of remembering where each one goes in a particular job.

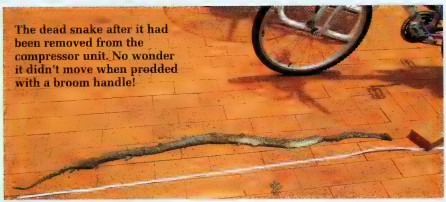
The last thing we want to do as repairers is install a long screw where a short one should go. During the last few years, I've seen many laptops come into my workshop where an amateur repairer has put a 'too-long' screw in to hold the case together, only to see it go right through to the keyboard side.

Punching holes in a laptop chassis is bad enough but screwing the wrong fastener through someone's LCD panel is even worse! And since this is something I really want to avoid when con-

continued on page 37

Serviceman's Log – *continued*

The snake in the air-conditioner



The dead snake after it had been removed from the compressor unit. No wonder it didn't move when prodded with a broom handle!

Servicemen frequently encounter dead rodents, cockroaches and other nasties inside electrical equipment. A. F. of Kingscliff, NSW recently encountered a large snake and it was really on the nose. Here's his story . . .

Did the snake eat the rat before the snake died or did the snake die by electrocution on an empty stomach? That was the thought running through my mind as I recently surveyed the damaged wiring inside a faulty air-conditioner.

This little saga had started four days earlier, when a neighbour complained to me of a foul smell in her garden. I took a quick sniff and the smell was certainly unpleasant but I fobbed her off by saying that another neighbour had probably spread some organic fertiliser around. And besides, it was too hot to do anything!

Unfortunately, by the fourth day, the smell had become unbearable and in spite of the heat, it was time for a search to track down the source of the problem. The smell seemed to be coming from the side of her house but it was difficult to tell as the wind kept gusting. There was nothing along the side of the house except a strip of grass and the outside compressor unit of a split-system air-conditioner.

This was the area where the smell was strongest but there was only the compressor box that could hide anything. I then spotted two large black horse flies sitting on the top of the compressor unit. Was that a clue as to the origin of the smell?

There was only one way to find out. The compressor unit had a small cover on one end, which allowed the electrical cables to enter the casing. I thought that removing this might give me some quick insight as to what the problem was, as it was easier to remove this than the eight self-tapping screws which held the top down. As a result, I removed the cover, took a peek inside and quickly stepped back when I saw a snake's skin.

Now when I left school, I was conscripted straight into the army. We were young and green and were not smart enough to question any authority. Of course, there was lots of training and one of the basic questions which you had to get right was "what steps would you take, if you saw the tail fins of a mortar bomb sticking out the ground?"

The correct answer was "large ones sir and to the rear". I was glad that I'd remembered my basic training when I saw that snake; my memory must still be OK!

Keeping my distance, I waited for the snake to slither out of the compressor unit but it stayed there. After waiting some time, I cautiously advanced and rapped on the top of the box but still the snake did not appear. I then gave the box a mighty thump to dislodge any living thing that might be inside but still there was no movement

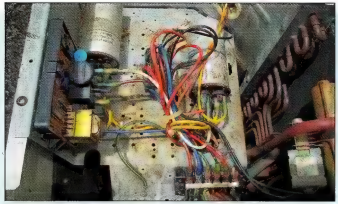
Eventually, I plucked up my courage, removed the screws from the lid and gently lifted it free, holding it in front of me as a shield. A large carpet python (which later measured 1.65 metres long) was lying across a circuit board near the top of the compressor and its extremities disappeared down into the lower parts of the unit. And it wasn't moving.

I took a long-handled broom and poked the snake but still it did not move. It certainly appeared to be dead but were there others lurking inside? I cautiously examined every nook and cranny that I could see but nothing seemed to be alive in there.

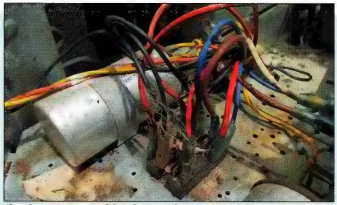
I now had the unpleasant task of removing this creature from the compressor unit while hoping that it didn't return to life. Fortunately, there wasn't much chance of the latter occurring – after four days in the summer heat, the snake was well and truly maggot-ridden and it was stinking to high heaven.

Extracting this 1.65-metre snake

The carpet python measured 1.65 metres (5-feet 5-inches) long and really wasn't in the best condition! Was that bulge in its body, near its tail, the remains of a rat?



This view inside the compressor unit shows the wiring and control PCB section where the snake was found.



The damage caused by the rat chewing through the wiring insulation can be seen here. It set a deadly trap for the snake.

from the intricacies of the compressor unit was an extremely unpleasant task but eventually the job was done and the carcass disposed of. The smell inside the compressor unit then quickly lessened and I was able to closely inspect it for damage.

It was just as well I did because next to the circuit board that the snake had been draped across was a large rat's nest. And the rat had shown a fondness for the plastic insulation around the electrical cables and spade connectors. It had chewed away quite a lot of the insulation, leaving lots of exposed copper wires.

What's more, as the rat had chewed at the insulation, it had pulled strands of the copper wire out from the insulating sheaths, creating a nest-like web. It was a real mess.

Closer examination revealed that the rat had chewed the leads that led to the fan motor, which I assumed must have been powered down when ever it did this (probably at night). Unfortunately for the snake though, the fan motor relay must have energised while it was crawling through bared copper wires to get at the rat and so the snake was electrocuted! What amazing timing!

Well, that was my first impression when I started the repair. But was it "amazing timing"? Several weeks later, when I was at home at my desk, I looked at the damage to one of the cables using a magnifying glass. And I spotted the telltale signs of three blackened copper strands with balls of melted copper at the ends.

That threw a different angle on the grisly scene. I now believe that the rat chewed through the insulation of the Neutral wire without being shocked. However as the strands of copper broke with the chewing, eventually there were only three strands left and these subsequently melted with the inevitable current overload.

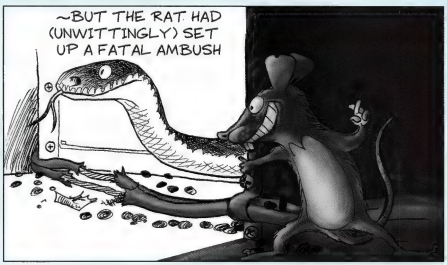
When these strands melted, the strands of copper on the fan motor side suddenly jumped from Neutral potential to Active potential, ie, 230VAC. Some time later, the python slithered past and was electrocuted when it brushed against these 230VAC strands on the fan motor side – an electrocution aided by the fact that other parts of the snake's body would have been touching the sheet metal housing which was at ground potential.

What irony! The snake was hunting the rat but the rat had unwittingly set up a fatal ambush.

The repair involved much more work than just replacing the chewed cables and the damaged connectors. I also had to remove most of the unit's side panels, to get at the numerous rats' nests that had been built around the compressor motor and piping. It was necessary to remove these, otherwise they would be a fire hazard.

The circuit boards were cleaned by pouring hot water over them and lightly scrubbing them with a brush. They were then thoroughly dried before being refitted. The air-conditioner was then tested and it worked perfectly.

I'm still wondering whether the rat was eaten by the snake before the latter was electrocuted or whether the rat got away, to wreak havoc on another piece of electrical gear.



fronted with lots of different screws, I always draw out a plan of the board or chassis and make decent notes as to what goes where.

The Yashica camera was the first repair job that I made such notes on and I've done it as a matter of course ever since. It also pays to make very clear and understandable notes; it could be weeks before you put a device back together and there is nothing worse than thinking you've got it covered with

Beyonwiz PVR repairs

Goods damaged in transit are one of the risks when buying online. Fortunately, regular contributor B. P. of Dundathu, Qld was able to straighten out a dented PVR (personal video recorder) he bought recently via eBay. Here's his story . . .

PVRs have now replaced VCRs for recording TV programs for later viewing. This change came about because PVRs are easier to use and was also prompted by the introduction of digital television. Analog TV transmissions have now been switched off in most areas, making VCRs much less useful than before as they cannot receive digital TV.

Recently, I decided to update our SD PVRs to HD PVRs. My daughter already had a Beyonwiz FV-L1 HD PVR and liked it, as it's capable of recording two channels at the same time. As a result, I thought I would try eBay to see what was available in this brand. There were several brand new units listed, along with a few used models. After some thought, I decided to bid on some of the used models, as this would save a substantial cash outlay. I initially obtained an older "DP-S1" model with an in-built DVD player, which arrived safely and worked well. I then purchased a "DP-Lite i" which again worked well.

Some time later, I found a "DP-P2" model being advertised and I was again successful with my bidding. It duly arrived but you can imagine my dismay when I opened the box and found that the bottom of the unit had been stoved in.

The seller had done what I would call an adequate job of packing the unit, so what had gone wrong? It appeared that a very heavy weight had been placed on top of the box, resulting in damage to the bottom of the unit. Fortunately, that the seller had packed the unit upside-down, otherwise the top of the unit would have been damaged instead.

I pondered what to do. I didn't want to power up the unit at this stage because if the bottom of the case was contacting the PCB, doing so could result in irreparable damage. I thought of contacting the seller but in the end decided to see if I could repair the unit. I was almost certain that the internals were undamaged and I decided to take a chance that this was indeed the case.

The first step was to break the warranty seal. I then removed the lid by removing the four screws from the back and the single screw from each side.

Once inside the unit, it was apparent that I would need to remove the HDD (hard disk drive) before I could remove the PCBs. After unplugging all the cables, I removed the four screws securing the HDD, extracted it from the case and put it aside. I then removed the power supply and logic boards, after which I removed the rear panel.

It was then just a matter of straightening the bottom panel. This was done by hand since the metal was fairly thin and easily bent back to into position. Once it was all done, I reassembled the unit, connected it to a TV set, plugged it in and turned it on. Fortunately, it was still in good working order and none-the-worse for its ordeal.

Non-working unit

When I purchased that last unit on eBay, I also noticed a Beyonwiz "DP-Lite i" that was listed as "not working or for parts". The seller described it as having a hard drive issue and had initially thought that the hard drive could not be formatted.

Suspecting that the original HDD was faulty, he had replaced it with a brand new HDD only to find that the fault persisted. He'd then researched various internet forums and the popular opinion was that it was a power supply problem, so he had decided to sell the unit as "not working or for parts".

This unit had been listed on two previous occasions and I had already made an offer which had been rejected. Offers from several other bidders had been rejected as well.

This was getting the better of me, as I wanted to see if the unit could be repaired. Even if it wasn't repairable, I would still end up with a spare 500GB hard drive and a spare remote

diagrams and hand-written records only to find that the notes you made are inadequate.

It's also a good idea to take lots of digital photos, especially with complex repair jobs or those held together with dozens of different screws.

As mentioned, my Yashica was extremely well made. I suppose all good-quality cameras are made that way but this was my first experience with cameras and I was impressed. I ended up using a few specialised tools to get into the thing but it all went smoothly.

First, I removed the front housing of the camera, exposing all the internal workings. Then, after removing every visible screw, I removed the plastic framework, along with the mirror and shutter assembly which came out in one piece. That was about as far as I was comfortable taking things, though. Any further and I seriously doubted that I'd be able to reassemble it, despite my youthful naivety and bravado.

When I inspected the mirror and the now-exposed lenses, prism and viewfinder assemblies it didn't take long to spot the spot. It was very small and appeared to be a piece of rubber or something of a similar texture. The fragment was stuck to the face of the prism inside the top of the body and it took a bit of picking at it to dislodge it from the glass.

Under the magnifier, it had a definite edge to it on one side and looked like it could have been part of a seal, washer or mounting bush that had come adrift on impact. However, even after a very close inspection, I couldn't see anywhere obvious where it could have come from.

Next, I gave the interior a good blow-out with dried, low-pressure compressed air. During this procedure, I gently tapped and shook the body just in case there were any other fragments floating about inside but nothing else fell out. All that was left to do was reassemble the parts in reverse order but first I gave the interior optics a good going over with a lens-cleaning cloth.

It was a pleasure to have a spot-free

control, which would be worth having as this model's remote operates all the different Beyonwiz models except for the DP-P2.

I decided to re-submit my previous offer and this time, it was accepted. The unit arrived a few days later and I immediately hooked it up and turned it on. When I did this, it displayed a message stating that the hard drive would be initialised.

I cancelled this operation, turned the machine off and unplugged it. I then removed the lid, expecting to see several electrolytic capacitors in the power supply with bulging tops. However, at first glance, all looked good. I then thought that I would remove the power supply board and test the capacitors. However, before going to all that bother, I decided that I would first try replacing the SATA cable to the HDD.

I dug out an old PC SATA cable, swapped it over and again powered up the unit. This time, I opted to initialise the hard drive and the process completed successfully. I then tuned in the channels and all appeared to be working correctly.

But was it going to be as easy as that? I had an uneasy feeling that it had all been too straightforward, so I decided to reinstall the original SATA cable to confirm that it was indeed faulty but again, all was well. And that meant that the fault lay elsewhere.

Next, I removed the logic board and inspected the SATA socket carefully with a magnifying glass. I wasn't entirely happy with the soldering on the socket's pins, so I re-soldered them and refitted the board.

I then decided to check the ESR of the electrolytic capacitors on the power supply board, as I suspected that this was where the problem really lay. As a result, I removed this board and it was then that I noticed an almost imperceptible bulge at the top of C30, a 470µF 16V electrolytic.

When I tested its ESR, it was very high at 1.6Ω, so it was obviously faulty. I then checked the remaining electrolytic capacitors on the power supply board. All were OK except for C38 (470µF 25V) which had an ESR of 0.32Ω. While this wasn't exceptionally high, it was high enough to cause concern.

I replaced both faulty capacitors, then reassembled the unit, set it up to record several programs and left it to do its thing for a few weeks. During that time, I used it to periodically watch live TV (ie, via its tuner) and to view recorded programs and it functioned flawlessly.

This was a 'win-win' situation. The seller got a fair price for his 'dead' PVR and I paid less than I would have had it been in good working order. I was then able to repair it for little more than the cost of my time.

Once again, my trusty ESR meter saved the day and a faulty piece of electronic equipment was successfully repaired. I built my ESR meter from a Jaycar kit many years ago and it has proved invaluable over the years for finding capacitor faults in all sorts of equipment.

MISS THIS ONE?

Published in Dec 2012

2.5GHz 12-digit Frequency Counter

with add-on GPS accuracy

Wow! 10Hz - >2.5GHz in two ranges; 1us - 999,999s with a 12-digit LED display. It's a world beater and it's the perfect addition to any serious hobbyist's bench – or the professional engineer, technician, in fact anyone who is into electronics! You'll find it one of the handiest pieces of test gear you could ever own and you can build it yourself.

All the hard-to-get bits (PCBs, micros, LEDs, panels, etc) are available from the Silicon Chip PartShop.

You'll find the construction details at http://siliconchip.com.au/project/2.5ghz

PCBs, micro etc available from PartShop

down. A single screw and several plastic clips hold it all together so it wasn't rocket science to expose the screen and associated internal connections.

Like Yashica, Sony has made an art out of squeezing incredible amounts of electronics into tiny spaces – and space really is at a premium inside the screen bezel. Several strips of Mylar (or similar material) with embedded tracks run from the camera's logic boards to the screen and my guess was that one of them wasn't seated properly. I was praying it hadn't split or cracked because that would be a real can of worms I didn't want opened.

There were seven connections altogether where the straps terminated into PCB-style ZIF (Zero Insertion Force) connectors. I re-terminated each one by flipping up the plastic tensioner bar to release the strap, cleaning the strap's gold connections with isopropyl alcohol, and then sliding it back into the socket and clicking home the tensioner bar to lock it in place.

Fortunately, my efforts paid off because this completely resolved the screen scrolling issue. I'm not sure what I'd have done if it hadn't! Tricky things, cameras. SC

viewfinder again and thankfully, that was the only time I ever had to pull the camera apart. That camera subsequently took thousands of photographs before being retired once digital cameras superseded it.

Sony Handycam

Another camera that's done the hard yards with us is our trusty Sony Handycam. Its not only travelled with us but has also taken a few tumbles in the quakes, with one long, deep scratch in the housing evidence of where something fell onto it after it had fallen to the floor.

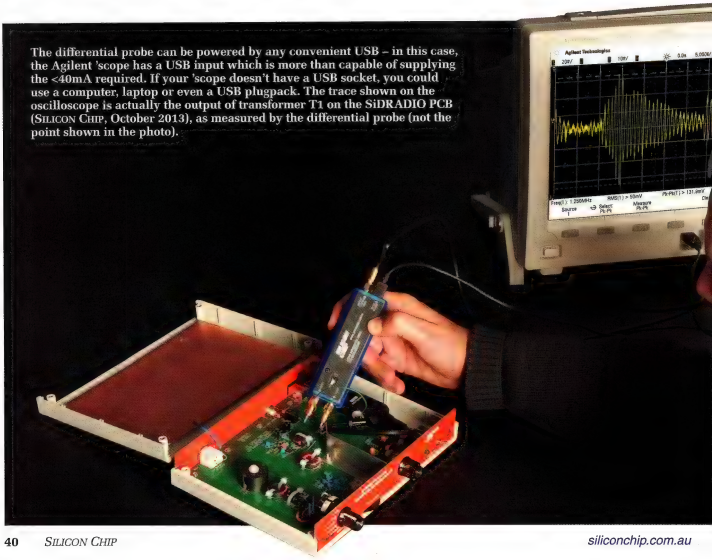
Despite these battle-scars, it still takes excellent video and still shots. However, not long ago, it developed a problem with the fold-out side screen, the image on which recently began slowly scrolling like Dad's old black and white TV used to do.

In Dad's case, he'd just mutter something unprintable and tweak the knobs around the back of the set to stabilise the image. When it comes to the Handycam though, there are no knobs to twiddle. However, I did discover that applying some gentle pressure to the screen's hinge area slowed the scrolling down.

With that discovery, my serviceman's nose began to twitch and I went looking for a suitable screwdriver so that I could start stripping the screen

WIDEBAND, ACTIVE DIFFER OSCILLOSCOPE

Using your oscilloscope to examine and measure high speed and high frequency circuits can be tricky if you use only the usual passive test probes supplied. Here's a design for a high performance, active differential probe which costs much less than commercially available active probes. It has very little circuit loading and usable bandwidth of more 80MHz.



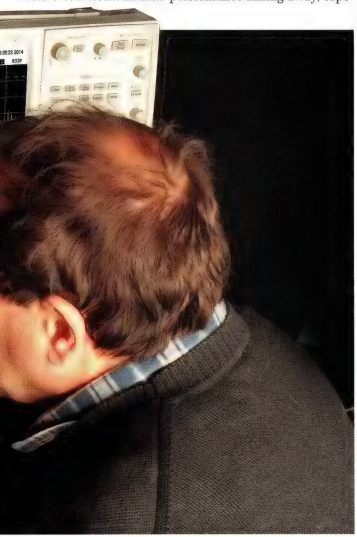
The differential probe can be powered by any convenient USB – in this case, the Agilent 'scope has a USB input which is more than capable of supplying the <40mA required. If your 'scope doesn't have a USB socket, you could use a computer, laptop or even a USB plugpack. The trace shown on the oscilloscope is actually the output of transformer T1 on the SiDRADIO PCB (Silicon Chip, October 2013), as measured by the differential probe (not the point shown in the photo).

By JIM ROWE

ENTIAL PROBE

Do you know what is inside the 'passive' test probes supplied with most oscilloscopes, and how to use them to make reasonably accurate measurements at high frequencies?

If not, have look at the excellent article on this topic by Doug Ford in the October 2009 issue of SILICON CHIP. Doug explains how complex these probes can be and how many factors can result in their performance falling away, especially at high frequencies. In addition they tend to disturb operation in the circuit being tested, making it difficult to make proper measurements.



It's because of the shortcomings of passive probes that some of the big manufacturers produce 'active' probes to provide a much higher input resistance together with a much lower input capacitance.

Originally, active probes used valves (vacuum tubes) at their input but then when semiconductor technology came along, JFETs and MOSFETs made it possible to make active probes that were much smaller and easier to use.

It also became feasible to make 'differential' active probes, which overcame some of the remaining drawbacks with conventional 'single ended' active probes. (More about these shortly.)

The big problem with commercial active probes is their price tags. Even the single-ended type can set you back well over $700, while the differential type can cost over $2000 apiece – more than most of us paid for our digital scopes!

In short, the only way that most of our readers are likely to be able to use an active probe with their scope is to build one. Yet the last DIY active probe to be described in Australia was way back in the September 1989 issue of ELECTRONICS Australia – 25 years ago. That design is now very dated.

This new active, differential scope probe design takes advantage of modern surface-mount components to deliver a high level of performance and it fits inside a compact case. Best of all, it can be built for much less than the cost of any currently available commercial active probes.

We estimate that you should be able to buy all of the components and build it for about a quarter of what you'll pay for the cheapest commercial active probe presently available.

Why differential?

Before we start describing the new probe and how it works, perhaps we should look at why a differential active probe tends to be better than a single-ended one.

A single-ended active probe is certainly a big improvement over most passive probes, offering high input resistance combined with very low input capacitance.

It tends to cause lower disturbance to the circuit under test, particularly at high frequencies – where the higher input capacitance of a passive probe causes increased circuit loading.

The high frequency and transient response of the probe-plus-scope combination also tends to be better and smoother, due to better compensation and fewer reflections in the cable between the probe output and the scope input.

But there can still be problems when you're making HF measurements with a single-ended active probe. These problems are mainly associated with the 'ground clip lead', which is used to make the connection between the probe's input and the earthy or 'cold' side of the circuit under test.

As you can see from Fig.1A, even when the ground clip lead is quite short, it can introduce enough inductance (L_g) to reduce the effective signal voltage appearing at the actual input of the probe at high frequencies.

So the frequency response of the probe tends to droop at high frequencies, reducing the measurement reliability.

As well, the ground lead inductance can interact with the probe's input capacitance (C_{in}), resulting in resonances

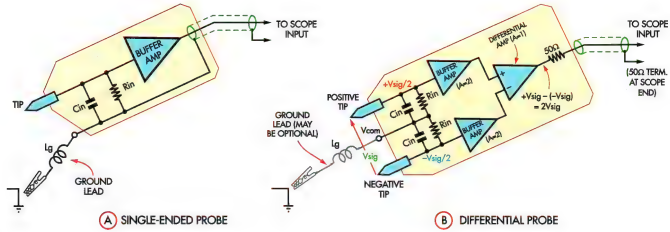


Fig.1: Comparing a 'single ended' active probe (A) with a differential active probe (B). With a single ended probe the ground lead inductance Lg can cause problems at high frequencies, but a differential probe solves these problems.

at specific high frequencies.

This can not only result in the probe producing unwanted loading on the circuit being measured but can also produce spurious 'peaks and dips' in the measurements.

It is possible to minimise these problems by replacing the ground lead with a very short 'ground blade', providing a somewhat lower inductance than the usual 100mm-or-so long ground lead and clip.

Many of the commercial single-ended active probes come with this type of ground blade as an accessory. But a better solution is to change over to a differential probe, as shown in simplified form in Fig.1B.

As shown, the differential probe has two tips and is designed to measure the signal difference between the two – rather than the signal between either probe tip and ground.

In fact the ground lead (or blade) is really only used to tie the circuit under test's ground to that of the probe and scope, to keep the voltages being measured within the probe's common mode input range.

This means that if there is no significant voltage difference between the two grounds, the ground lead or blade may be regarded as optional.

Inside the differential probe there are two virtually identical input buffer amplifiers (one from each tip), each of which feeds one input of a third amplifier, the differential amplifier. This is where one of the two signals is subtracted from the other to send only the 'difference' signal out to the scope input.

This subtraction cancels out any 'common mode' signal present at both probe tips, leaving only the 'difference

Specifications

An active differential probe for oscilloscopes, housed in a compact handheld case and operating from +5V DC, derived from any convenient source such as a USB port on a PC or digital oscilloscope. It provides tip area illumination via a white LED and a choice of two switched gain settings: 1:1 or 10:1.

Input coupling:	AC
Input resistance, each probe tip:	1MΩ nominal on the 1:1 range (1.0023MΩ); 10MΩ nominal on the 10:1 range
Input capacitance, each probe input socket to ground:	3.15pF approximately. (So capacitance tip-to-tip is approximately 1.6pF.)
Maximum DC voltage at probe tips:	±45V, both ranges
Maximum AC voltage input before overload, both probe tips:	2.0V peak-to-peak (700mV RMS) on the 1:1 range, 20.0V peak-to-peak (7.0V RMS) on the 10:1 range
Output impedance:	50Ω (Needs an output cable of 50Ω characteristic impedance, terminated in 50Ω at the scope end.)
Bandwidth (probe + output cable and termination):	25Hz - 80MHz +0.2dB/-3dB, both ranges 60Hz - 50MHz +0.2dB/-0.5dB, both ranges 150Hz - 40MHz +0.2dB/-0.3dB, both ranges
Overall transmission gain/loss:	On 1:1 range, 0.0dB ±0.6dB On 10:1 range, -20dB ±1.0dB
Current drain from 5V DC supply:	Less than 40mA

This photo, close to life size, shows the Active Differential Probe in its handheld instrument case. It's a comfortable fit in the hand while applying the probe to the circuit under test.

signal' – the signal between the positive and negative probe tips, which is what we are trying to look at and measure.

As the common mode signal is essentially equal to the voltage V_{COM} at the probe's ground terminal, this explains why any voltage difference developed across the ground lead or blade inductance L_G is no longer a problem. It's simply cancelled out.

Before we leave Fig.1, you may be wondering why we've shown the output of the differential probe as having an amplitude of 2Vsig. Won't this cause a calibration problem, by giving the probe a gain of 2?

Not really, because as shown in Fig.1B, there's a 'source termination resistor' of 50Ω fitted in series with the probe output. This is to match the characteristic impedance of the probe's output cable (normally 50Ω).

Then at the scope end of the same cable, another 50Ω shunt resistor is used to ensure that the cable is terminated correctly at that end too, to avoid reflections and consequent complications (like peaks and dips).

And the combined effect of the two termination resistors is to introduce an attenuation factor of 2:1 – bringing the overall signal gain of the probe and cable back to unity.

The probe's circuit

Now refer to Fig.3, which shows the complete schematic of our new probe. The two probe input tips plug into CON1 and CON2 at left, from where they each pass to the end contacts of S1a and S1b – the two sections of range switch S1.

Depending on the setting of S1, they each pass into the two input buffer amplifiers directly or via a series 9.0MΩ input divider resistor comprising three 3.0MΩ 1% resistors in series.

Then each signal passes through a DC blocking capacitance comprising a 1µF capacitor in parallel with a 10nF capacitor.

This combination has been chosen to give a lower input corner frequency of less than 30Hz, together with the smoothest possible upper frequency response.

Following the DC blocking capacitors the signals each pass through 27Ω overload protection resistors, before reaching the gates of input buffer transistors Q1 and Q2.

These are BSS83 N-channel MOSFETs designed especially for operating from a 5V supply voltage. We're using them as near-unity gain wideband source followers, to give high input impedance combined with the lowest possible input capacitance.

The gates of both Q1 and Q2 are biased to +4.3V via the 1MΩ resistors. This bias level is chosen to provide a 'half supply voltage' (+2.5V) level at the sources, which are direct coupled to the following ICs. The bias voltage is

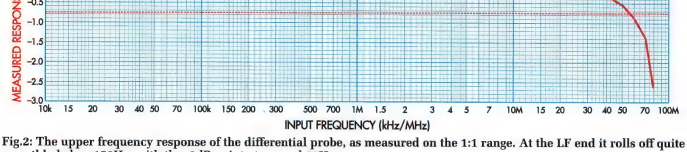
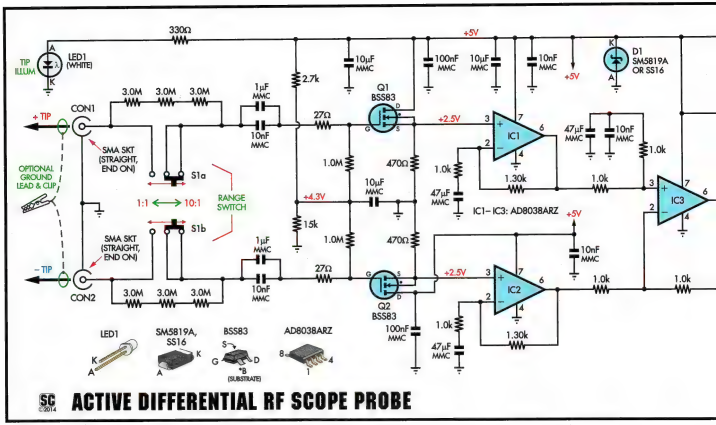


Fig.2: The upper frequency response of the differential probe, as measured on the 1:1 range. At the LF end it rolls off quite smoothly below 150Hz, with the -3dB point at around 25Hz.



ACTIVE DIFFERENTIAL RF SCOPE PROBE

derived via the 2.7kΩ + 15kΩ voltage divider, with a 10µF bypass capacitor to provide filtering.

10:1 attenuator

The 1MΩ gate biasing resistors also provide the main component of input resistance for both input channels, when switch S1 is in the '1:1' position. Then when S1 is moved to the '10:1' position, they form the lower elements in the 10:1 input dividers (in conjunction with the 9.0MΩ series resistors).

After passing through input buffer transistors Q1 and Q2, the two input signals pass through amplifiers IC1 and IC2.

These are AD8038ARZ wideband amplifiers, specified for operation from a single 5V supply and with a bandwidth of better than 150MHz (for a gain of 2.0).

Incidentally, we also looked at several other devices, including the AD818, MAX4414ESA and OPA356 but none performed as well as the AD8038ARZ. So the 8038 it is!

We are using them here as buffer amplifiers with a gain of 2.3, to compensate for the small loss in the input source followers Q1 and Q2 – while also providing the current drive capability to feed the inputs of difference amplifier IC3. The two 47µF capacitors connecting the 1.0kΩ 'lower feedback' resistors to probe earth are to maintain the LF response.

IC3 is also an AD8038ARZ device, configured so that the positive-tip input signal is fed to its positive input (pin 3) while the negative-tip signal is fed to the negative input (pin 2).

The four 1kΩ resistors and 47µF + 10nF bypass capacitors ensure that IC3 does perform the desired subtraction of the two signals, so a '2Vsig' difference signal appears at its output (pin 6).

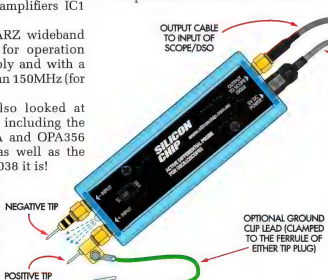
The two paralleled 100Ω resistors at the output of IC3 provide the 50Ω 'source termination' for the cable connecting the probe's output at CON3 to the scope input and the paralleled 100µF and 100nF capacitors provide DC blocking.

LED tip illumination

Finally, LED1, located at upper left is included to illuminate the area right in front of the probe's tips, to make connections easier.

Many of the up-market commercial active probes also provide this 'tip illumination', because when you are making measurements in high frequency circuits you'll almost certainly be using very short tips on the probe itself. This means that the probe body will not only shield the immediate area of the circuit being tested from a light source, but will also tend to block your view as well.

In other words, it's a very worthwhile feature and one which was easily provided at low cost.



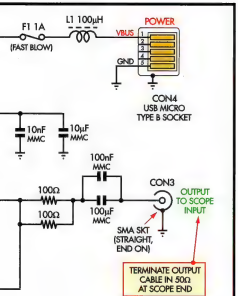


Fig.3: The probe's full circuit schematic. All components except range switch S1 and LED1 are SMD devices.

Parts List – Active Differential Oscilloscope Probe

1	ABS instrument case, 114 x 36 x 24mm	(Hammond 1593DTBU - element14 code 187-7372)
2	PCBs, 103 x 26mm, code 04107141 & 04107142	
1	100µH SMD inductor, 1.6A rating (L1)	(Murata 48101SC)
1	1A SMD fuse, 0603 fast acting (F1)	(Cooper Bussman 0603FA1-R)
1	DPDT/DIL slide switch, raised actuator (S1)	(TE Connectivity ASE 2204)
3	SMA socket, end launch, PCB edge mtg (CON1,2,3)	(Emerson Connectivity 142-0701-806 or Multicomp 19-70-4-TGG)
1	Micro USB type B socket, SMD (CON4)	(FCI 10103594-0001LF or Molex 105017-0001)
8	Self-tapping screws, 6G x 5mm long	
Semiconductors		
3	AD8038ARZ SOIC8 video amplifier (IC1,2,3)	(RS Components order code 523-6872)
2	BSS83 MOSFETs, SOT-143 SMD pkg (Q1,2)	(element14 order code 108-1312)
1	3mm white waterclear LED (LED1)	
1	60V 1A Schottky diode, DO214AC SMD pkg (D1)	(SS16 or SM5819A)
Capacitors		
1	100µF MLCC, SMD 1210, X5R dielectric 6.3V rating	*(Code 107)*
3	47µF MLCC, SMD 1210, X5R dielectric 6.3V rating	*(Code 476)*
4	10µF MLCC, SMD 1210, X7R dielectric 16V rating	*(Code 106)*
2	1µF MLCC, SMD 1206, X7R dielectric, 50V rating	*(Code 105)*
3	100nF MLCC, SMD 1206, X7R dielectric 50V rating	*(Code 104)*
6	10nF MLCC, SMD 1206, X7R dielectric 50V rating	*(Code 103)*
		NB: not all SMD capacitors are marked. If in doubt, measure!
Resistors (all 0.125W 1%, SMD 1206)		
6	3.0MΩ	*(Code 3M0 or 3004)*
2	1.0MΩ	*(Code 1M0 or 1004)*
1	15kΩ	*(Code 15K or 1502)*
1	2.7kΩ	*(Code 2K7 or 2701)*
2	1.30kΩ	*(Code 1K3 or 1301)*
6	1.0kΩ	*(Code 1K0 or 1001)*
2	470Ω	*(Code 471 or 470R)*
1	330Ω	*(Code 331 or 330R)*
2	100Ω	*(Code 101 or 100R)*
2	27Ω	*(Code 270 or 27R)*

The codes shown here are the two most common but there are others! If in doubt, check all SMD resistors with your multimeter as you would any doubtful resistor.

The whole probe runs from a +5V DC supply which means that it can be powered via virtually any standard USB port, such as the one on the front of many recent-model digital scopes, a USB port on your PC – or if neither of these are available, one of those low-cost 'USB charger/power pack' devices you can pick up for less than $15 (preferably not a dodgy "el cheapo" from China!).

Since the total drain of the probe is less than 40mA, this should be well within the capability of most USB ports on DSOs and PCs.

CON4 is used to bring the +5V DC power into the probe. This is a USB micro type-B socket, which allows you to use a standard 'USB type A-plug to USB micro type-B plug' cable (as used to hook up tablet PCs and mobile phones to a PC or charger) to provide the probe with power.

100µH inductor L1 is used to filter the +5V input and remove any noise from the USB port or charger, while fuse F1 and diode D1 are used to protect against reversed-polarity damage.

These components do nothing if the 5V supply is connected with the correct polarity but if the polarity should be reversed for any reason, D1 will immediately conduct and cause F1 to 'blow' – protecting both the probe circuitry and the 5V source from significant damage.

Construction

All of the probe circuitry and components are fitted onto a PCB measuring 103 x 26mm (code 04107141). This is designed to fit inside one half of a small handheld ABS plastic case, with a screening PCB of the same size (code 04107142) fitted into the other half of the case.

The case itself measures only 114mm long, 36mm wide and 24mm high, so it can be held in your hand very comfortably. In fact, the case has been designed to house hand-held equipment such as this. It comes from Hammond Manufacturing.

The small SMA sockets (CON1 and CON2) used for connection of the probe's input tips are mounted at one end of the case, along with the white LED1, which illuminates the tip. Two sockets are mounted at the other end, SMA output socket (CON3) along with CON4, the USB micro B socket for the probe's 5V DC power.

All of the components used in the probe are mounted directly on the main PCB and all but two of the components are SMDs (surface-mount-devices).

The two through-hole exceptions are slide switch S1 and LED1. Switch S1 is mounted under the PCB and LED1 is mounted above it with its

leads bent forward by 90° so the LED's body can protrude through the 'front end' of the case between the two input sockets.

The component overlay diagram of Fig.4 shows the location of all components, together with their orientation. When assembling the PCB, use a fine-tipped soldering iron – preferably one with temperature control.

We suggest fitting the components to the PCB as follows: first fit USB micro socket CON4, taking great care when soldering its five very small contacts at the rear. Then mount the resistors and capacitors, followed by fuse F1 (which is very tiny). Then fit diode D1, Mosfets Q1 & Q2 and the three ICs.

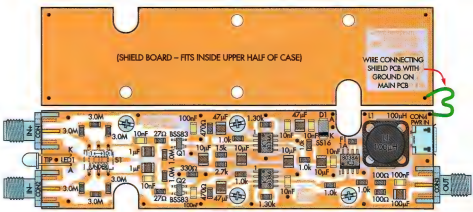
Next, fit the three SMA sockets (CON1, CON2 and CON3), which slide onto the front and rear edges of the PCB, with their centre pin resting on (and soldered to) the centre pad at the top of the PCB.

Their 'side prongs' solder to the matching pads on each side, on the top and bottom of the PCB.

Inductor L1 comes next, followed by LED1 on the top of the PCB and switch S1 underneath it in the position shown.

When you are fitting LED1 make sure you mount it vertically with the underside of its body about 13mm above the top of the PCB. After the leads are soldered they can both be bent forward (left) by 90°, so the LED can protrude from the centre hole in the case front end panel.

Finally fit slider switch S1. This is in a 6-pin DIL package, which mounts under the PCB with its pins coming up through the matching holes. Make sure you push the switch body firmly against the underside of the PCB before you solder its pins to the pads on the top of the board.



Your PCB assembly should now be complete, with all that remains being to connect the shield PCB copper to the ground copper on the main PCB.

This can be done using a short length of light hookup wire – baring a few millimetres at each end so that the ends can be soldered into the 'via' holes at the rear of each PCB, as shown in Fig.4.

Preparing the case

Now prepare the case. This involves drilling three 7mm holes in the removable 'front' end panel (for CON1, CON2 and LED1), together with another round hole in the 'rear' end panel for CON3.

Then there's an 8 x 3mm rectangular hole to be cut in the rear end panel as well (for access to CON4), and finally a 10 x 7.5mm rectangular hole cut in the bottom half of the case (which becomes the top) for clearance around S1 and access to its actuator.

The location and size of all of these holes is shown in Fig.5. You might also want to make a 'dress' front panel, to give your probe a professional look and help in using it. Artwork for a dress front panel is also shown in Fig.7.

You can make a photocopy of this, (or you can download it from **siliconchip.com.au** and print it), hot laminate it (or use self-adhesive book cover film) for protection and then attach it to the front panel using double-sided adhesive tape – after cutting it to size and also cutting out the clearance holes for the case assembly screws and S1.

Assembly

Now slip the front end panel of the case over CON1, CON2 and LED1 at the 'front' end of the main PCB, and the rear end panel over CON3 at the rear end of the PCB.

Then lower the complete main PCB-plus-end-panels assembly down into the bottom half of the case (which becomes the top), with the two end panels passing into the moulded slots and S1 passing down through its matching slot.

Once this main board assembly is down as far as it will go, you can secure it firmly in position using four 5mm long 6G self-tapping screws – mating

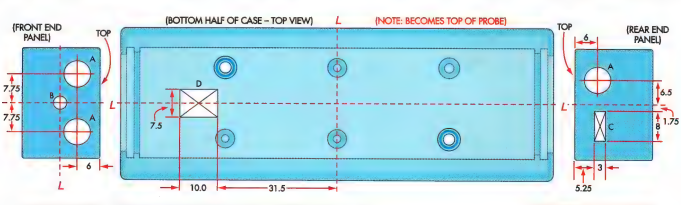


Fig.5: drilling and cutout details of the Hammond Manufacturing "Hand Held Instrument Case", shown 1:1. The only slightly difficult holes are the cutouts for the USB socket on the rear end panel and the switch on the lower half of the case.

Fig.4 (left): the component overlay for the main PCB with the shield board (which contains no components) above. It is connected to the main board by the short link as shown. The main board fastens to the bottom of the case, which becomes the top, while the shield is secured to the top of the case, which becomes the bottom!
Below is a same-size photo of an early prototype main PCB, actually mounted in the case. Take no notice of the "AD818" labelling – we actually used AD8038s as shown on the PCB overlay.

with the holes in the moulded standoffs underneath.

Then the shield PCB can be fixed into the other half of the case, using another four of the same screws.

The final assembly step is to invert the case half with the shield PCB and lower it down over the half with the main PCB, so that each end panel slips into the moulded slots as before.

Then you can upend it and fasten it all together using the two countersink-head self tappers supplied and your active differential probe should be complete.

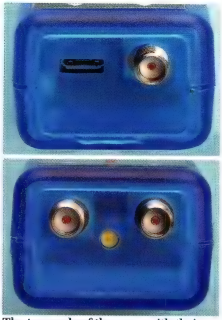
Making the probe tips

The simplest way to make 'basic' probe tips for the project is probably to base them on an SMA male connector, as shown in Fig.6.

This is the way I made the probe tips you can see in the photos, basing them on an Amphenol Connex type 132113 SMA plug; only the plug body and the centre contact are used – the crimping sleeve and PTFE spacer are not needed.

The steps in making the tips are shown overleaf. The actual tips are 20mm lengths of 1mm diameter nickel plated steel wire, cut from a large paper clip.

You might like to make a second pair of tips, fashioned in the same way but with longer lengths of wire – say 30mm

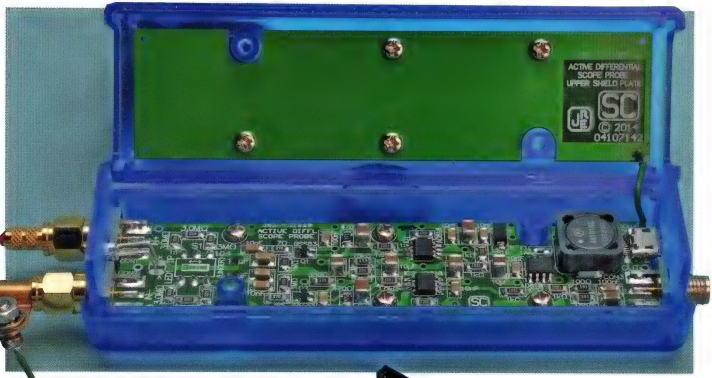


The two ends of the case, with their drilling/cutouts to suit the three SMA sockets, USB socket and white LED.

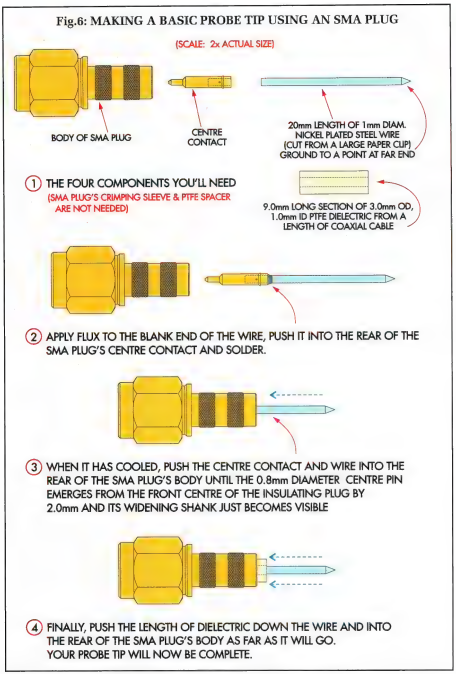
long – with a 'crank' in the centre to allow their tip spacing to be adjustable. This would be done simply by loosening their plug bodies and then rotating the tips as needed to set the tip spacing before tightening them again.

Ground clip lead

As mentioned earlier, a ground clip



Here's how it all goes together – the main PCB and the shield PCB screwed into their respective case halves. The SMA connectors and USB socket poke through the case ends.

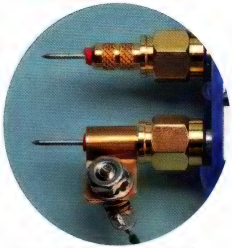


lead is often not necessary when you are using a differential probe of this kind. However you might like to make one up, so it will be available in situations where you may need it – or at least to see if it has any effect.

An easy way to make a suitable clip lead is to connect a suitable clip to one end of a length of flexible insulated hookup wire and then fit a small solder lug to the other end.

The solder lug can then be attached securely to a small clamp made of thin brass sheet and bent into a 'P' shape with an inner loop diameter of 4.5mm, so it will slip over the 'crimp ferrule' of one of your probe tip plugs (it doesn't matter which one).

Then a 3mm hole is drilled in the centre of the flat sections of the clamp, so a 6mm long M3 screw and nut can be used to attach the solder lug of the ground lead, while at the same time fastening the clamp to the plug ferrule.



Close-up of ground clip construction.

The close-up photograph above shows the idea. By the way you don't have to make the ground clip lead particularly short, because its inductance is not critical when you are using a differential probe. So feel free to make it any convenient length.

Other Uses

A differential probe can also be handy for measuring signals which are relative to other voltages in a circuit. Both signals must be within the probe's common mode input range and given that the probe is AC-coupled, you will only get the AC component of that signal.

For example, if you have a circuit with a signal that's relative to a 'half supply' rail, there may be ripple or signal injected into this rail. So using the differential probe would allow you to see the signal with this unwanted component removed.

Many scopes can perform this function using 'math' mode but that requires the use of two of your precious scope inputs and the result is generally a lot better when the subtraction is performed in the analog domain.

With this method, the circuit ground can remain earthed, allowing easy simultaneous measurement of the signal. SC

Fig.7: same-size front panel artwork to photocopy and glue to the hand-held instrument case for a professional finish.

Everyday is Dad's Day @ Jaycar

SEPTEMBER
ONLINE & IN STORE

Audio Receiver with NFC® & Bluetooth® Technology

Listen to music or take calls wirelessly up to 10m. Uses Bluetooth® technology for high quality stereo audio transmission, and NFC® (Near Field Communication) for one touch tap-and-pair with your phone. Weighs only 12g.

- Multi-funtional buttons
- NFC® and aptX® support
- Rechargeable battery
- Size: 34(L) x 34(W) x 12.5(D)mm

AA-2087

$44.95

12V Thermoelectric Cooler & Warmer

Cools to 18-20°C below ambient temperature, and heats up to 65°C. Great for camping trips and work sites. Low noise, fully insulated and thermoelectric. Lightweight and portable.

- 12VDC powered
- 14L capacity
- CFC Free
- Size: 490(L) x 270(W) x 305(H)mm

GH-1373

FATHER'S DAY GIFT IDEA!

$99

3D PRINTER KIT - BRING YOUR 3D CREATIONS TO LIFE!

Supplied as a DIY kit, once assembled you can turn 3D digital images into real life plastic objects. A very fast, reliable and precise 3D printer that won't break the bank.

Can print objects with maximum dimensions of 200 x 200 x 200mm, in either ABS or PLA plastics (available separately).

This is an advanced level constructional kit, average build time is 3 - 4 days. For more information on assembly and the tools required please visit our website. Extensive online community support is also available at: www.k8200.eu

TL-4020

DEAL! BUY 3D PRINTER AND GET 10% OFF SELECTED ACCESSORIES*!

NEW!

$1,299

Filament not included

ACCESSORIES TO SUIT:

3D Printer Controller Module*	TL-4022	$149.00
3D Printer LED Light*	TL-4024	$34.95
1.75mm PLA 3D Printer Filament*	TL-4060	$44.95
3.00mm PLA 3D Printer Filament*	TL-4062	$44.95
1.75mm ABS 3D Printer Filament*	TL-4070	$42.95
3.00mm ABS 3D Printer Filament*	TL-4072	$42.95

http://bit.ly/TL-4020

Jaycar Electronics

Better, More Technical

Great Father's Day Gift Idea!

IP67 True RMS DMM with Smartphone App

View live measurements, trend graphs, data log, and email your results or upload them to the Cloud - all from your Smartphone!

- CAT IV, 600V
- AC/DC voltages up to 1000V
- AC/DC current up to 10A
- Resistance, capacitance, frequency and more
- Bluetooth® and PC connectivity
- Data hold/storage

QM-1576

$219

DEAL! Buy QM-1576 & HB-6355 for $239 save $19.95

HB-6355 value $39.95

EtherTen, Arduino Compatible Board

Includes onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, and even Power-over-Ethernet support.

- ATmega328P MCU running at 16MHz
- Built-in 10/100base-T Ethernet

XC-4216

$69.95

SEE PAGE 8 FOR MORE ARDUINO PRODUCTS

Laboratory Switchmode Power Supplies

Compact size, high current, with variable output and fan cooling. Thermal overload and short circuit protected. Individual current and voltage backlit displays with LED fault indicator light.

- Analogue meter
- Size: 148(W) x 162(D) x 62(H)mm

0 - 24VDC 15A MP-3800 $149
0 - 16VDC 25A MP-3802 $199

FROM $149

NEW STORE AT SMITHFIELD

4C & D
16 Smithfield Rd
Smithfield
NSW 2164

PH: 02 9604 7411

LED Illuminated Magnifying Lamp

Magnify and illuminate objects. Great tools for technicians, researchers or for general hobby work that involves soldering, connecting wires between small parts, and other fiddly jobs.

- 5 dioptre lens
- Mains powered

QM-3548

$99

Rolling Floor Base for Magnifying Lamps

Mount a magnifying lamp to this base and you can roll it around the floor providing even greater flexibility in your work. Heavy base so it doesn't easily topple over.

- Suits QM-3548
- Size: 700(H) x 385(Dia)mm

QM-3549

$89

19" Rack Mount Enclosures

Ideal for studios, PA, sound reinforcement, IT, or phone system installations. Features 1.8mm solid steel powder coated cabinets with clear tempered glass doors.

- 6U
- Key lockable
- Size: 530(W) x 360(H) x 450(D)mm

FROM $129

Flat Packed HB-5170 WAS $159 NOW $129 SAVE $30
Assembled HB-5171 WAS $189 NOW $149 SAVE $40

12VDC Marine Grade Power Sockets

Marine grade cigarette power sockets rated up to 10A. Supplied with brackets for flush and surface mounting.

- Connects via 6.3mm spade terminals
- Includes under dash bracket (PS-2020 only)

Single (shown) PS-2020 $14.95
Dual PS-2022 $19.95
Single with LED Voltmeter PS-2024 $27.95
Single with 2 x USB Ports (1A + 2.1A) PS-2026 $29.95

NEW! FROM $14.95

2 Port USB Charger

High quality USB charger with 1.0A and 2.1A ports. Compatible with 12V and 24V battery systems and can be mounted in various options.

- Supplied with panel mount, under dash bracket, and a surface mount "hood"
- Connects via 6.3mm spade terminals
- Size: 36(Dia.) x 50(D)mm

MP-3616

NEW! $24.95

Self Powered LED Voltmeter

Easily monitor your battery voltage, or the voltage in any DC powered system. Supplied with a panel mount and a surface mount "hood".

- 5-30VDC
- Connects via 6.3mm spade terminals
- Size: 36(Dia.) x 26(D)mm

QP-5582

NEW! $22.95

Universal GPS Charger with Dual USB

Replacement for an original GPS charger, but with 2 x 2.1A high power USB outputs, for charging both a GPS and a Smartphone or other USB gadgets at the same time. Includes 1.2m USB cable with 6 replaceable connectors to suit most GPS models.

- Input: 12-24VDC
- Output: 5VDC, 4.2A max total
- Size: 100(L) x 42(W) x 25(H)mm

MP-3676

$29.95

In-Car FM Transmitter with Charger

Simply connect the transmitter to your iPhone®, iPod® or iPad®, select a frequency from 88.1 to 107.9MHz then tune in using your FM car radio. It has a built-in mic for hands-free communication and a USB port built into the cigarette lighter plug for charging other popular electronic devices.

- Working voltage: 5VDC
- Backlit LCD display
- Size: 100(L) x 30(W) x 120)mm

AR-3124

$29.95

12/24VDC FM Transmitter/Charger

The rigid bracket holds your iPhone 5® or iPod touch 5® and charges the device through the lightning connector for handsfree functionality.

- Streams music via the car radio
- Size: 110(H) x 65.5(W) x 40(D)mm

AR-3125

iPhone® not included. Not compatible with iPhone® 5S

$49.95

12VDC Mounting LED Headlamp Modules

Extremely bright drop-in replacement LED headlights for your car. Each kit contains 2 x 25W per LED bulbs, 2 x controller assemblies, and all the wiring is pre-terminated to appropriate connectors to make installation as quick and easy as possible.

- CREE® XLamp CXA1512 LED
- Ballast size:65(L) x 50(W) x 16(H)mm

H4 (High / Low Beam) Cree® Module
• 1600/1800 Lumens per LED bulb
SL-3498 **WAS $149.00 NOW $149 SAVE $20**

H7 Cree® Module
• 1800 Lumens per LED bulb
SL-3499 **WAS $169.00 NOW $149 SAVE $20**

$149

Warning: State road and traffic authorities do not allow retrofitting of these products to cars with ordinary headlights - even if it's really simple to do so.

Slim Ballast HID Light Kits

HID provides far greater light output than standard automotive lights. This series of kits all feature a slim ballast design for ease of installation in engine bays and tight spaces.

FROM $49.95

- 12V 6000K
- 300% more light than halogen

H1 Slim Ballast HID Kit	**SL-3490**	**$49.95**
H3 Slim Ballast HID Kit	**SL-3492**	**$49.95**
H4 Slim Ballast HID Kit	**SL-3494**	**$49.95**
H4 Slim Ballast HID High + Low Kit	**SL-3495**	**$79.95**
H7 Slim Ballast HID Kit	**SL-3496**	**$49.95**

Note: Please ensure your lights are angled correctly. These lights are not ADR approved.

LIMITED STOCK

Pen Light with COB LED

Nifty LED pen light with magnetic pocket clip for hands-free operation. Very bright 90 Lumen COB (chip-on-board) LED runs up to 20 hours.

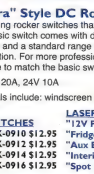
NEW! $12.95

- Requires 3 x AAA batteries
- Size: 165(L) x 30(D) x 16(W)mm

ST-3466

500 Lumen 10W LED Worklight

Suitable for illuminating a warehouse, automotive workshops etc.



- High brightness, long life LED
- IP65 rated
- Rechargeable

SL-2809

$74.95

500 Lumen Mini LED Vehicle Lights

Amazingly bright. Shock and waterproof alloy housing. Equivalent to a 35W halogen. All-round solution for many different applications. Operated from 10-36VDC.

- Spot or flood beam patterns available
- Stainless steel mounting hardware
- Compact size 70(H) x 40(W) x 55(D)mm
- Sold individually

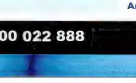
Flood	**SL-3915**	**$49.95 ea**	
Spot	**SL-3916**	**$49.95 ea**	

$49.95 ea

Buy 2 for $89.90 SAVE $10

8A Heavy Duty Battery Charger

Suitable for both 6 and 12 volt car, boat, motorcycle and lawnmower batteries up to 6 amps. Switched between trickle or heavy duty charge rates.



$59.95

- 4-stage LED charge indicators
- Overload and reverse polarity protection
- Complies with Australian Electrical Safety Regulations

MB-3522

"Condura" Style DC Rocker Switches

Superb looking rocker switches that you see in 70-100ft luxury motor cruisers. Basic switch comes with double-LED illumination, a standard rocker cover and a standard range of decals to customise the switch to your application. For more professional finish, special laser-etched covers are available to match the basic switches.

- Rated 12V 20A, 24V 10A

Typical decals include: windscreen wipers, horn, heater & many more.

NEW! $12.95

SK-0910 SK-0920

BASIC SWITCHES

White	**SK-0910 $12.95**
Red	**SK-0912 $12.95**
Blue	**SK-0914 $12.95**
Amber	**SK-0916 $12.95**

LASER-ETCHED COVERS

"12V Power"	**SK-0920 $2.95**
"Fridge"	**SK-0921 $2.95**
"Aux Battery"	**SK-0922 $2.95**
"Interior Light"	**SK-0923 $2.95**
"Spot Lights"	**SK-0924 $2.95**
"Horn"	**SK-0925 $2.95**
"Rear View Camera"	**SK-0926 $2.95**
"Inverter"	**SK-0927 $2.95**
"Driving Lights"	**SK-0928 $2.95**
"Thermofan"	**SK-0929 $2.95**

Portable Fridge/Freezers

Keep your food and drinks fresh and cold! Equipped with renowned Danfoss® compressor and control module, these portable fridges features digital display control panel, internal LED light, and 3-stage battery protection.

- Superb energy efficiency and reliability.
- Powered by either 12/24VDC or 240VAC
- Uses just 0.7A per hour

Four models available:

30L Fridge/Freezer	**GH-1600 $695**
40L Fridge/Freezer	**GH-1602 $749**
50L Fridge/Freezer	**GH-1604 $825**

Accessories available:

30L Insulated Bag	**GH-1601 $59.95**
40L Insulated Bag	**GH-1603 $69.95**
50L Insulated Bag	**GH-1605 $74.95**

GH-1600

GH-1601

FROM $695

Slide Drawer for Portable Fridge/Freezers

If you're planning to install your Powertech fridge/freezer in the back of your 4WD, installing with one of these slide drawers is a very secure & convenient way to go.

- Locks in 3 positions
- Handles up to 100kg load

GH-1609

DUE EARLY SEPTEMBER

NEW! $299

LET US REWARD YOU

REGISTER ONLINE TODAY!

Semi-flexible Solar Panels

These 12V flexible solar panels offer performance at an affordable price. No heavy rigid frame makes them light and portable. Both units have a fully sealed terminal box with approx 1.2m of power cable with PVC outer sheath.

20W
- Short circuit current: 1.24A
- Weight: 0.78kg

ZM-9112

$99.95

100W
- Short circuit current: 5.69A
- Weight: 2.8kg

ZM-9116

$399

ZM-9112

Pure Sine Wave Inverters

Suitable for a variety of mobile and permanent power installations. Provides standard protection (overload, high temperature, over/under input voltage and output short circuit) as well as host of additional features to improved performance and reliability under adverse conditions. Range from 180 to 2000W.

FROM $199

- USB port
- 12VDC input, 230VAC output

180W	**MI-5700**	**$199**
360W	**MI-5702**	**$239**
800W	**MI-5704**	**$449**
1100W	**MI-5706**	**$649**
1500W	**MI-5708**	**$899**
2000W	**MI-5710**	**$1,149**

MI-5700 MI-5710

See online for Modified Sine Wave Inverters

Deep-Cycle Gel Batteries

These are genuine deep-cycle batteries that can be operated and charged in any position. Leakproof and completely sealed. Ideal for solar power, 4WD, camping, etc.

- 12VDC

26Ah	**SB-1698 $129**
38Ah	**SB-1699 $189**
100Ah	**SB-1695 $379**

FROM $129

DEAL!
*FREE Battery Conditioner (NA-1420) valued at $7.75

*Valid with purchase of SB-1698, SB-1699 & SB-1695

SB-1698

SB-1695

SB-1699

9 Step Switchmode Battery Charger

Fully automatic 25A high current charger with maintenance charging of all types of lead-acid batteries (SLA, Gel and AGM) as well as lead-calcium batteries from 50 - 500Ah, either 12V or 24V. Microprocessor controlled and protected against user error, so is totally safe to leave connected for months at a time. Perfect for caravan and boat users. See our website to download full product info sheet.

- IP44 rated
- Input: 170 - 260VAC, output: 12/24VDC
- Current: 4A max
- Size: 260(L) x 135(W) x 70(H)mm

MB-3608 **WAS $399.00**

$349 SAVE $50

SLA Battery Boxes

Designed to suit larger SLA batteries or your standard car battery. Perfect for mounting in your boat, trailer or caravan. Includes mounting clamps and lid strap to secure the box properly in place.

To suit 40Ah SLA Batteries
HB-8100 WAS $24.95 NOW $19.95 SAVE $5

To suit 100Ah SLA Batteries
HB-8102 WAS $29.95 NOW $24.95 SAVE $5

FROM $19.95 SAVE $5

Snap On Battery Terminals

Used for protecting the exposed positive/negative battery connections from dust, grime or other build up. Ideal for automotive, marine, or industrial use.

- Rated at 500A
- Red and black supplied

HM-3087

Battery not included

$14.95

Universal Programmable Battery Charger

Charges, discharges and balances Li-ion, Li-Po, Ni-Cd, Ni-MH and lead acid batteries. Particularly suited to radio control hobbies. It can be powered with a mains plugpack or directly from a 12V battery or any other DC source from 10 - 18 volts.

- Microprocessor controlled
- Delta V charging detection
- 2, 3, 4, 5 and 6 cell balanced charging outputs

MB-3632

$79.95

12V 8A Dimmer/Motor Speed Controller

The pulse width modulation (PWM) used in this controller allows you to vary intensity of a 12V device from 0 to 100% with high efficiency. Operating on any 12V system at up to 8 amps, the circuitry is fully potted and the control potentiometer is splash proof.

- Suitable for harsh or wet conditions
- Size: 95(L) x 47(W) x 26(H)mm

MP-3209

$27.95

Flexible LED Strip Light

Over 1,000 lumens of brilliant white light to light up under your awning, inside a tent, or anywhere else around the campsite. Fitted with hook and loop backing for quick and easy hanging.

- IP67 waterproof
- 12VDC, 1.0A
- 1.2m long light
- 5m long cord

ST-3950

$89.95

IP67 Sealed Waterproof Connectors

XLR

A matching IP67 waterproof plug and socket suitable for harsh environments. Great for use with PA gear and cabling that are used in outdoor conditions.

NEW!
$9.95

XLR Line Plug	PP-1013 $9.95
XLR Line Socket	PS-1017 $9.95

2.1mm DC Power

Features a standard 2.1(ID) x 5.5(OD)mm DC connector set. Pre-fitted with a 100mm pigtail lead, allowing you to make up your own lead set. Very handy!

- Cables are 20AWG
- 3A max at 12VDC

PS-0785

NEW!
$7.95

2.5mm Stereo

Available in panel mount socket and line plug models.

Panel Mount Socket
PS-0789 $14.95
Line Plug with 1m Cable
PP-0787 $12.95

FROM
$12.95

RJ45

This set of connectors makes it safe to use RJ45 connectors in harsh environments.

- 15/16"-20 UNEF thread locking

RJ45 Socket	PS-1450 $27.95
RJ45 Plug	PP-1452 $14.95
Cap to Suit	PP-1454 $8.95

FROM
$14.95

Snap Fit ABS Enclosures

Range of black ABS cases with side flanges allowing wall, or ceiling mount. Snap fit design that locks together to enclose the circuit board or project inside.

- Includes 2 x wall mount holes (4.5mm Dia.) and 4 x internal holes (2.0mm Dia.)
- 4 sizes available

HB-6006

70(L) x 50(W) x 27(H)mm	HB-6006 $3.95
90(L) x 50(W) x 42(H)mm	HB-6007 $4.95
100(L) x 80(W) x 43(H)mm	HB-6008 $5.45
127(L) x 70(W) x 50(H)mm	HB-6009 $5.45

NEW!
FROM
$3.95

ABS Enclosures with Snap-in Hinged Lid

Made of high impact resistant ABS plastic, these enclosures can withstand wide range of temperature and humidity fluctuations. Snap-in design for easy opening and closing without using any tools.

- Four internal moulded standoffs to mount PCB horizontally

Available in 2 sizes, either light grey or black.
HB-6431 & HB-6433 - 91(L) x 79(W) x 48(H)mm
HB-6432 & HB-6434 - 91(L) x 122(W) x 68(H)mm

Grey, 1-Way Cable Entry	HB-6431 $5.95
Black, 1-Way Cable Entry	HB-6433 $5.95
Grey, 2-Way Cable Entry	HB-6432 $7.95
Black, 2-Way Cable Entry	HB-6434 $7.95

NEW!
FROM
$5.95

HB-6431

Digital 2.5L 170W Ultrasonic Cleaner

Features a generous 2.5L 304-grade stainless steel bowl, controllable heating element and digital controls. Stylish cabinet design and very well built.

- Tank Capacity: 2500ml (Max 2100ml, Min 600ml)
- 5 selection time settings
- Weight: 2.5kg
- Size: 290(W) x 223(D) x 185(H)mm

YH-5412

NEW!
$149

Portable Storage Cabinet

Perfect storage solution for fasteners and other small parts. Unique "double lock" design on each storage box keeps contents in their bins when shut. Commercial grade.

- 12 storage compartments
- Size: 300(W) x 310(H) x 145(D)mm

HB-6301

NEW!
$29.95

DUE EARLY SEPTEMBER

Pro Gas Soldering Tool Kit

This kit contains a Portasol Pro Piezo Gas Soldering Iron, cleaning sponge and tray, 2.4mm double flat tip, hot air blow, hot knife tip, hot air deflector and flame tip.

- Quality storage case
- 15-75 Watts (adjustable)

TS-1318

$129

DEAL!
Buy TS-1318, get 50% off NS-3045

"Silver" Solder

5 times stronger that regular solder and 100% lead free. Will join all metals excluding aluminium. Use with a soldering iron, torch.

- 96% tin, 4% silver, cadmium free
- Includes 14g solder with 14g of flux

NS-3045

$19.95

Reinforced Plastic Tool Set

Handy tool set that won't rust! Supplied as a one-piece mould - simply snap out the tools you need.

- Includes scraper, tweezers, spanners (M1.6/M2/M2.6/M3/M4), grip (driver) with many common heads

TD-2116

NEW!
$4.95

DUE EARLY SEPTEMBER

Liquid Electrical Tape

This liquid can be used instead of insulation tape. Simply brush it on and it will insulate and seal out moisture.

- Acid & salt resistant
- 28g tube

Black	NM-2836 $12.95
Red	NM-2838 $12.95

$12.95

"DURALAC" Anti-Corrosive Jointing Compound

Used religiously in marine, aircraft and other fabrication industries as an essential corrosion inhibiting material to seal joints between dissimilar metals of all types, including magnesium and alloys.

- 115ml tube

NA-1026

$32.95

Hook-up Wire Pack

Quality tinned hook-up wire on plastic spools. 8 rolls included, each roll a different colour.

- 25m on roll

WH-3009

$34.95

*Conditions apply. See website for T&Cs

REGISTER ONLINE TODAY!

SIGN UP NOW & BE REWARDED

Earn a point for every dollar spent at any Jaycar Company store* & be rewarded with a $25 Rewards Cash Card once you reach 500 points!

Register online today by visiting
www.jaycar.com.au/rewards

Limited stock on sale items

13.8VDC Regulated Switchmode Power Supplies

High current general workshop power supply for equipment, component testing etc.

- Input voltage: 190 - 240VAC
- Banana socket style binding posts
- LED power on indication
- Rear mounted M205 fuse

12A MP-3079 $69.95
40A MP-3089 $199.00

FROM **$69.95**

120W Stepdown Transformer

Quality fully-enclosed stepdown transformer with fold up metal carry handles, approved 3-wire power cord & US style 2 pin
110 - 115V socket.

- 120W 240V - 115V Isolated
- 120VA, 1.0A rated

MF-1080

$99

Also available:
250W 240V - 115V Isolated
MF-1082 $129

0-260VAC Variable Laboratory Autotransformer (Variac)

Controls AC votage and of voltage-dependent parameters such as current, power, temperature, light intensity, motor speed etc. It enables the AC input to a mains powered appliance to be easily varied from 0 to full line voltage (or greater). Encased in heavy-duty steel housing.

- Rated power handling: 500 VA (fused)
- Input voltage: 240VAC @50Hz
- Output Voltage: 0 - 260VAC @50Hz
- Size: 165(D) x 120(W) x 160(H)mm

MP-3080

$229

Test & Measurement

Power Point and Leakage Tester

Test your power points using this versatile tester. It checks most types of power points within 110V to 240V for correct wiring and earth leakage circuit breaker trip levels.

QP-2000

$19.95

Plug-In USB Datalogger

Log temperature and humidity readings. Download to PC via USB.

- Temp range: -40˚C to 70˚C
- 32,000 memory samples

QP-6013

USB / LCD Readout Type also available QP-6014 $149

$119

LED Headband Magnifier

Leaves both hands free and can be worn over prescription or safety glasses. Ideal for jewellery, radio electronics, & camera repair etc.

- Adjustable head strap
- Built-in LED work light
- 1.5x, 3x, 8.5x or 10x magnification
- Requires 2 x AAA batteries (SB-2426 $1.95)

QM-3511

$29.95

Cat III True RMS DMM with Temperature

A powerful true RMS multimeter that includes non-contact voltage testing, backlit LCD, and a carrying pouch.

- 4000 count, 600V
- Temp range: 20°C to 760°C
- Voltage, current, resistance, capacitance, frequency and more
- Powered by 1 x 9V battery (included)

QM-1551

$59.95

Non-Contact Thermometer with Dual Laser Targeting

Measure the temperature of any surface from a safe distance with this compact sized non-contact thermometer. With a wide temperature range and laser targeting, this portable instrument is easy to use for quick and accurate temperature checking of any surface.

- Temp range: -50˚C to +650˚C / -58˚F to +1202˚F (±1%)
- Size: 146(L) x 104(W) x 43(D)mm

QM-7221

$99

Desktop LED Magnifying Lamp

Sixty LEDs provide ample illumination, perfectly even light and the 3x and 12x magnifying lenses will show all the detail needed. Being LED, there's no delay in startup and they'll never need replacing. Ideal for hobbies, modelmaking or jewellery etc.

- Size: 320(H) x 95(Dia.)mm

QM-3544

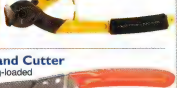
$49.95

300mm Copper Cable Shears

Features a precision cutting head forged from carbon steel attached to drop forged steel handles for extra leverage. Cuts copper cable up to 35mm² and any cable up to 2GA.

- 310mm long

TH-1900



NEW! **$24.95**

Heavy Duty Crimp Tool

Heavy duty and ergonomic crimper that uses quick interchangeable dies, no screwdriver needed. Has Ratchet mechanism for max power and quick release.

TH-2000

Quick interchangeable dies available:

6P6C RJ11/12	TH-2001	$17.95
8P8C RJ45	TH-2002	$17.95
Insulated Terminals	TH-2003	$17.95
BNC/TNC RG58/59/62	TH-2004	$17.95
F Connectors CATV RG6/59	TH-2005	$17.95
Non-Insulated Terminals 26-18AWG	TH-2006	$17.95
Non-Insulated Terminals 20-10AWG	TH-2007	$17.95
SMA/Fibre Optic 1.09-6.48mm	TH-2008	$17.95
SMA/Fibre Optic 1.07-4.52mm	TH-2009	$17.95

NEW! **$49.95**

Stainless Steel Wire Stripper and Cutter

Strip wire sizes from 0.6mm to 2.6mm. Spring-loaded with locking jaws. Soft rubber handles for added comfort.

- Strips stranded wire from 12-24 AWG and solid wire from 10-22 AWG
- Will also cut steel wires up to 3.0mm
- 164mm long

TH-1841

NEW! **$15.95**

270˚ Rotation Clamp Vice

The base will clamp to any bench or table up to 55mm thick and the 40mm jaws will take a job up to 58mm in size. Once in position, the head is easily fixed in position with a quick release lever.

- Base size: 115(W) x 94(D)mm

TH-1769

$19.95

Pocket Size Gas Blowtorch

Fully self-contained butane 1300˚C portable blow torch. Simple press button Piezo ignition, flame control and safety lock. Refillable with butane gas (NA-1020). Ideal for hobby use, low temp silver soldering, heat shrinking etc.

- Size: 95(H) x 55(L) x 26(W)mm

TH-1610

NEW! **$16.95**

For suitable Butane Gas use **NA-1020 $5.95**
For Silver Solder use **NS-3045 $19.95**

100 Piece Driver Bit Set

The ultimate driver bit set. It has a magnetic bit holder, square to hex socket drivers, & square to hex bit adaptor. See website for full list of bits.

- Snap lock case

TD-2038

$19.95

4 Input HDMI Switcher

Switches between up to 4 HDMI sources. Supports resolution up to UHD 4K x 2K and also features 3D capability as well as TOSLINK audio output.

NEW!
$94.95

- Inputs: 4 x HDMI
- Output: 1 x HDMI
- Resolutions: All resolutions up to 4K x 2K
- Audio formats: Dolby TrueHD, DTS-HD Master Audio 7.1CH
- Compliant with HDMI 1.4a, CTS 1.4a, DVI 1.0, and VESA
- Size: 146(L) x 70(W) x 24(H)mm

AC-1707

4 Input HDMI Switcher with Audio Return

Switch between four HDMI sources to one HDMI equipped display. Features Audio Return Channel (ARC) to allow audio signals to be returned from the TV display to sound system.

NEW!
$119

- Inputs: 4 x HDMI
- Outputs: HDMI, TOSLINK, 3.5mm stereo
- Supported resolution: Up to 4k x 2k / 3D TV support / 1080p / 1080i / 720p / 720i
- Digital Audio Support
- Dolby TrueHD
- DTS-HD Master Audio 7.1CH
- Size: 191(L) x 83(W) x 25(H)mm

AC-1709

HDMI 4 x 2 Switcher/Splitter with UHD 4K Support

Distribute up to four HDMI sources to 2 displays simultaneously. Supports resolution up to UHD 4K x 2K as well as 3D and EDID.

- Inputs: 4 x HDMI
- Outputs: 2 x HDMI
- DTS digital, Dolby Digital, DTS-HD and Dolby TRUE HD
- Size: 85(W) x 192(D) x 26(H)mm

AC-1714

NEW!
$119

3G SDI & HDMI Converter

Allows HDMI equipped TVs and PC monitors to playback uncompressed 2.970Gbps digital footage from cameras supporting this format over long distances.

NEW!
$99.95

- Size: 80(L) x 43(W) x 23(D)mm

3G SDI to HDMI Converter AC-1727 $99.95
HDMI to 3G SDI Converter AC-1729 $99.95

HDMI Over 2 x Cat5e/6 - 30m with IR Extender

Transmits HDMI and IR signals across distances up to 30m over two common Cat6 cables.

- HDMI 1.3b and HDCP1.1 / DVI1.1 compliant
- 1080p signals up to 30m
- Size: 100(L) x 65(W) x 25(H)mm

AC-1730

NEW!
$64.95

HDMI Repeater with IR Extender

A clever device that allows you to hide your HDMI audio/video sources in cabinets or behind walls but still be able to control them.

NEW!
$99

- 1080p signals up to 45m

AC-1641

Centre Speaker with Bracket

2 x 2.5" full range speakers rated at 15WRMS, housed inside a rectangular shaped speaker box to suit most existing systems. Supplied with an adjustable swivel mount bracket for wall installations.

NEW!
$39.95

- Size: 170(H) x 110(W) x 89(D)mm

CS-2463

10" Portable PA System with 7 Channel Mixer

Lightweight PA system which includes 2 x 100W speakers, 7-channel mixer and a microphone. Features built-in DSP effects, peak indicator and a variety of controls to fine-tune the audio frequency range. It can also play MP3s from an SD card or a USB flash drive.

$399
SAVE $100

- Class D amplifier
- Mains powered
- Size: 320(L) x 320(W) x 475(H)mm

CS-2549 **WAS $499**

LIMITED STOCK

FATHER'S DAY GIFT IDEA!

Fibre Optic Audio Leads

A range of fibre optic TOSLINK cables with superb build quality. Suitable for achieving excellent audio reproduction in home cinemas that support Dolby Digital 5.1 (AC-3) surround sound, DTS, and more.

FROM
$14.95

1m **WQ-7301 $14.95**
3m **WQ-7302 $24.95**
5m **WQ-7303 $39.95**

Concord RCA Leads

Stereo parallel cables utilising 99.96% pure OFC and 24 carat hard gold plated contacts.

- 2 x RCA plugs to 2 x RCA plugs

0.5m **WQ-7227 $16.95**
1.5m **WQ-7226 $18.95**
3.0m **WQ-7228 $24.95**
5.0m **WQ-7230 $29.95**

FROM
$16.95

Economy HDMI Leads

Cost-effective solution without compromising quality or performance. Gold plated connectors. HDMI 1.4 standard with Ethernet classification.

1.5m WV-7915 $19.95
3.0m WV-7916 $24.95
5.0m WV-7917 $39.95

FROM
$19.95

Plasma, LCD & LED TV Wall Brackets

Mount your TV on the wall for a better view. Features solid steel construction, safety lock for security (CW-2822 and CW-2826 only) and are VESA standard compliant. Mounting hardware and instructions included

Suits Panels 23" to 37" Up to 45kg
CW-2826 $39.95

Suits Panels 32" to 60" Up to 80kg
CW-2822 $89.95

Suits Panels 23" to 37" Up to 45kg (Rotation and Tilt)
CW-2829 $109.00

Suits Panels 32" to 60" Up to 80kg (Rotation and Tilt)
CW-2825 $149.00

CW-2822

CW-2825

FROM
$39.95

Ceiling-Mount Projector Bracket

Designed to fit most of the projector models on the market, this bracket can be rotated through a full 360° and extends up to 370mm. Mounting hardware and instructions included.

- Rigid extruded aluminium construction
- Supports up to 15kgs
- Size: 182(W) x 235 - 310(H) x 182(D)mm

CW-2827

$79.95

Low Cost Home Automation

Don't spend tens of thousands of dollars to create a smart home. With our new low cost range of Wireless Home Automation, you can create a fully automated system and only spend a few hundred dollars.

Simple and easy to use, all sensors, controllers and swicth modules are operating wirelessly on 433MHz frequency at a max range of 100m (line of sight).

Home Automation Main Controller

A powerful controller with built-in 16 wireless alarm zones and 16 wireless home automation control. Easily interfaces with a wide range of wireless security devices such as a PIR motion detectors (LA-5157), magnetic reed switches (LA-5158), light sensors (LA-5598) and remote key fobs (LA-5155) to protect your home and property.

- Timer schedule programming
- Group programming
- Matrix (Scenes) programming
- 100 Alarm event memory
- 12VDC
- 240VAC power adaptor included

LA-5592

Accessories to suit:

Key FOB Remote	LA-5155	$19.95
PIR to suit	LA-5157	$49.95
Wireless reed switch to suit	LA-5158	$39.95

NEW!

$119

Wireless Bell Box

Works as an audible and visual deterrent, the siren produces a wailing 94dB of output and a powerful strobe when alarm is activated. Supplied with 240VAC mains power apdator.

- Voltage input: 12VDC
- Wireless Range: 100m line of sight
- Wireless Frequency: 433MHz
- Size: 340(L) x 200(W) x 75(D)mm

LA-5579

$109

240VAC Mains Switch Controller Module

Designed to be hard wired to your GPO, wall switches or other mains device, it enable you to remotely activate any mains appliances.

- Voltage input: 240VAC
- Wireless Range: 100m line of sight
- Wireless Frequency: 433MHz

LA-5594

$39.95

Also available:

12VDC Switch Controller Module	LA-5595	$59.95
240VAC Mains Light Dimmer Module	LA-5596	$39.95

*Note: A licensed electrician is highly recommended to hard wire this device into 240V mains wiring.

Wireless Light Sensor Module

Interfaces with the home Automation System to turn an output device on or off.

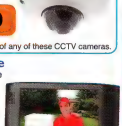
- Adjustable light setting
- Voltage Input: 12VDC
- Wireless Range: 100m line of sight
- Wireless Frequency: 433MHz

LA-5598

$39.95

Wireless Infrared Controller

Mount on the roof to directly control your household appliances. Will learn your appliances infrared remote command and repeat them when matched with a home automation input device.



- Up to 150m² size of operation
- Voltage input: 12VDC
- Wireless Range: 100m line of sight
- Wireless Frequency: 433MHz

LA-5597

$79.95

Mini Colour CCTV Cameras

Quality SHARP colour CCD cameras, featuring adjustable focus lens and composite video output to feed into DVR or TV for security and monitoring purposes.

- 420TV Lines
- 12VDC

Colour Pinhole[1] (shown)
QC-3692 $49.95

Colour CCD with IR[2]
QC-3694 $49.95

$49.95 ea

High Resolution Cameras with IR Illumination

Feature a high quality colour CMOS sensor and IR LEDs for night time illumination. Supplied with power supply and 18m combined video/power lead.

- 600 TV Lines
- Up to 10m range
- 12VDC

QC-8632

Outdoor Bullet Camera (IP66)[1]
QC-8632 $99
Dome Camera[1]
QC-8633 $99

$99 ea

Vandal Proof Mini Dome Camera

Access your CCTV system via the Internet or your local intranet. Access the camera through a web interface by hitting the IP address of the device and logging in. The web interface allows you to adjust visual settings, record, take snapshots and setup scheduled recording.

- H.264/MJPEG video compression
- CMOS camera sensor
- 12VDC, PoE
- Size: 110(Dia.) x 54(H)mm

QC-8626[1]

$299

[1]Valid with purchase of any of these CCTV cameras.

Free CCTV Sticker (LA-5101) Value $2.95

Peephole Viewer with Image Capture

Displays video from the other side of your door on a clear 3" LCD screen. MicroSD card required for image capture (sold separately **XC-4992 $47.95**) triggered by adding either the knock or PIR sensors (sold separately).

- Requires 2 x AA batteries
- Peephole tube diameter: 12mm
- Peephole tube length: 33 to 45mm
- Viewer size: 158(H) x 87(W) x 32(D)mm

QC-3735 **WAS $225.00**

$199
SAVE $26

Optional sensor modules:
PIR Motion Sensor
QC-3736 WAS $84.95 NOW $69.95 SAVE $15
Vibration Knocking Sensor
QC-3737 WAS $44.95 NOW $39.95 SAVE $5

Wireless 7" Colour Video Doorphone

Monitor the front door of your home or office without the need to run wires. The weatherproof outdoor camera can be powered from the included power supply or from 6 x AA batteries (not included). The AV signal transmits wirelessly to the 7" colour monitor. It also records any visitors you had while you were out, saving the footage to an SD card (available separately).

- 2.4GHz for transmission up to 100m
- Weatherproof (IP55) camera with rain shield

QC-3621

$299

8 Zone Wireless Alarm Kit

Everything you need to get a basic wireless system set up in your home! Includes key fob remote control, backlit LCD control panel, PIR sensor and two reed switches.

- Back-up battery
- Size: 210(L) x 113(W) x 127(H)mm

LA-5145

$149

See online for our full range of spare accessories.

Indoor Commercial Grade Doorway Beam

An entry buzzer designed for use in shops, restaurants, doctors and dentist surgeries, workshops etc to alert you to the entry of customers and visitors.

- Mains adaptor included
- Up to 6m range
- Adjustable alarm time & volume

LA-5193

$79

Accessories to suit:

Infrared Beam	LA-5179	$99.00
Door Counter	LA-5197	$34.95
Door Extension Buzzer	LA-5188	$34.95

Jaycar Electronics — Better, More Technical

BUILD IT DAD

ICSP Programmer for Arduino

Program new applications into a wide range of microcontrollers using this ICSP programmer with a USB interface. Compatible with a wide range of microcontrollers, including all Arduino boards.

$24.95

- Supplied with a USB cable and ISP programming cable

XC-4237

IR Temperature Sensor Module

Connect this to your board and point it at a surface or heat source to remotely measure its temperature. This is our special version of the industrial infrared remote thermometer units with an onboard power supply, communication support and a software library with examples supplied.

$34.95

- 3.3 to 5V operation
- -33 to +220°C measurement range, 1 second response time

XC-4260

4 Channel PoE Midspan Injector for Arduino

Power up to 4 EtherTen's (XC-4216) or EtherMega's (XC-4256) with DC from a low cost plugpack across your home or office network cables. It isolates and powers the correct wires automatically.

$26.95

- 4 channels of input/output jacks

XC-4254

4D Systems Intelligent Module with Touch

Add an interactive touch screen to your existing Arduino project. Includes a 3.2" LCD colour display with resistive touch and multiple input/outputs, a 4D Arduino shield and 5 way interface cable.

$119

XC-4280

Blue Dot Matrix LED Display Panel

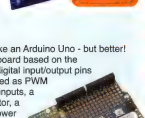
This large, bright 512 LED matrix panel has onboard controller circuitry designed to make it easy to use straight from your board.

- 32 x 16 high brightness blue LEDs (512 LEDs total) on a 10mm pitch
- Viewable over 12 metres away

XC-4251

NOTE: Can for comparison only

Also available:
Red Large Dot Matrix LED Display Panel
XC-4250 $39.95



$89.95

ARDUINO COMPATIBLE BOARDS

EtherTen

Includes onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, and even Power-over-Ethernet support.

- ATmega328P MCU running at 16MHz
- 10/100base-T Ethernet built-in

XC-4216

$69.95

Also available: Mega Prototyping Shield to suit XC-4257 $17.95

See instore or online for more

Eleven

The "Eleven" is just like an Arduino Uno - but better! It's a microcontroller board based on the ATmega328 with 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

XC-4210

$39.95

RFID Door Lock Shield Kit

This shield enables your Arduino to control a door lock using an electric strike plate and one of a number of commonly available RFID modules.

- Supported readers include ID12, ID20, RDM630, RDM880, and HF MultiTag

XC-4215

$29.95

Terminal Shield

Breaks out all the Arduino headers to handy screw terminals, making it easy to connect external wires without using a soldering iron. Ideal for quick experiments or for robust connections!

- Gold-plated surface
- Large prototyping area

XC-4224

$16.95

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Savings off Original RRP.
Prices valid from 14th August 2014 to 23rd September 2014.

Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock.

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www.electronex.com.au

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The Electronics Design and Manufacture Conference delivers the latest information on a host of topics.

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SILICON CHIP

Australian Technology Park - Sydney 10-11 September 2014
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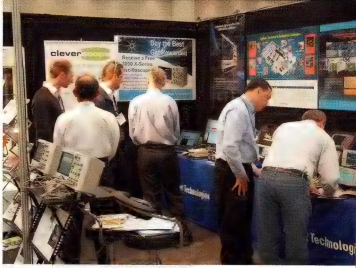
PCB FEATURE

ElectroneX
electronics design & assembly expo

This year the ElectroneX exhibition returns to Sydney (Australian Technology Park, Eveleigh, September 10-11). While the exhibition covers all aspects of electronics from components and design through to assembly, the concurrent SMCBA conference means there is a focus on PCBs and surface mount technology. SILICON CHIP (also exhibiting at ElectroneX - stand A32) is pleased to support ElectroneX and showcase many of the organisations also at this month's



ElectroneX
electronics design & assembly expo

Now in its 5th year, Electronex – The Electronics Design & Assembly Expo – is regarded as the definitive event for the electronics industry. The expo alternates annually between Sydney and Melbourne and the last event in Sydney in 2012 attracted over 1200 engineers and decision makers from the electronics sector.

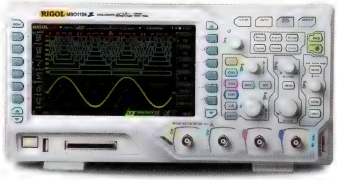
Improvements in design, system development and manufacturing assembly can be more easily achieved by keeping up to date with the latest technologies, products, development tools and industry knowledge base. The competitive future of practically every Australian industry sector is increasingly dependent on the utilis ation and integration of the latest electronics into all aspects of production, assembly, systems development, maintenance and service.

Design, electronic and electrical engineers, OEM, scientific, IT and communications professionals are invited to attend the event where they will find the latest technology driving future product and system developments. This specialised trade event continues to enjoy strong growth and is the pre-eminent electronics technology showcase and conference in Australasia.

Electronex comprises a major trade show, with more than 90 companies represented, that will showcase and demonstrate the latest new product releases for industry, scientific and commercial applications.

The SMCBA – Electronics Design & Manufacture Conference is being held in conjunction with the exhibition. This year's conference will feature several acclaimed international presenters and deliver a wealth of information on electronics design and manufacture as well as new streams on Embedded Systems and New Product Development.

New Rigol MSO1000Z Mixed Signal Oscilloscopes at Electronex



Emona Instruments will launch the new Rigol MSO1000Z series mixed signal oscilloscopes at the Emona Instruments stand, B1, at Electronex 2014.

The MSO1000Z series are the latest in Rigol's popular range of oscilloscopes. Rigol have built a solid reputation for quality and excellent performance, with thousands of units in use in educational institutions and industry around Australia. The new MSO1000Z series continue this tradition of quality and performance by providing advanced features at an affordable price.

The MSO1000Z series offer four channels, the choice of 70MHz and 100MHz bandwidth, as well as 16 digital channels. Sampling rate is 1GS/s and units come with 12Mpts standard memory with optional 24Mpts. Typical of Rigol oscilloscopes, the MSO1000Z series provide a fast 30,000wfms/s waveform capture rate and a unique optional 60,000 frames real-time waveform record and play-back, as well as UltraVision technology that provides multi-level intensity grading display.

While offering Australia's best value in mixed signal oscilloscopes, the MSO1000Z series also offer a variety of trigger and serial bus decoding functions (RS232, I^2C and SPI), wider vertical range (1mV/div~10V/div), lower noise floor, better for small signal capturing and optional in-built 25MHz dual channel Function/Arbitrary waveform generator. All units offer a wide range of interfaces USB Host, USB Device, LAN (LXI), AUX and include a large 7-inch TFT (800x480) WVGA display with multi-intensity waveform display.

If you can't get to Electronex 2014, contact Emona Instruments at 78 Parramatta Rd, Camperdown NSW 2050, Tel: (02) 9519 3933 or via their website, www.emona.com.au

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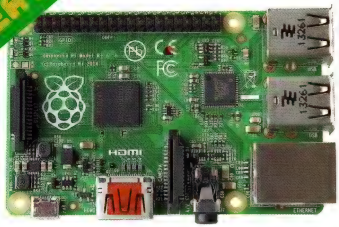
PCB ElectronEX FEATURE

Brand new Raspberry Pi B+ board



The new Raspberry Pi B+, now available from element14, is the first major update to the popular credit-card sized computer. It adds connectivity and power features to enable bigger and better projects.

The new board, which marks the first significant change to the multi-million selling credit card-sized computer, is priced at just $38. The new board offers more sensors and accessories than before, enabling users to build bigger and better projects.

Advanced power management and enhanced connectivity make it possible to power four USB accessories, such as 2.5 inch hard drive, through the device. Up to 1.2A can be delivered to the USB ports to connect power-hungry devices and accessories without needing mains power or an external USB hub.

Featuring a 40-pin extended GPIO interface, even more sensors, connectors and expansion boards can be added to the board, allowing users to increase the complexity of their Raspberry Pi projects. The first 26 pins remain identical to the original Raspberry Pi Model B for 100% backward compatibility.

The Raspberry Pi B+ is based on the same Broadcom BCM2835 Chipset and 512MB of RAM as the previous model. It is powered by micro USB with AV connections through either HDMI or a new four-pole connector replacing the existing analog audio and composite video ports.

The SD card slot has been replaced with a micro-SD slot, tidying up the board design and helping to protect the card from damage.

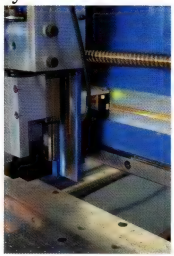
The B+ board also now uses less power (600mA) than the Model B Board (750mA) when running.

Since its launch in February 2012 over three million Raspberry Pi boards have been sold and the element14 Community has become one of the leading websites for discussion and collaboration around Raspberry Pi projects and developments.

With over 250,000 registered users the element14 Community is the largest online community for design engineers to share ideas, knowledge and solve challenges.

For more information on the new board or the Raspberry Pi phenomenon in general, call into stand B11 at Electronex 2014 or visit the element14 Raspberry Pi Community website at http://www.element14.com/raspberrypi

Prototype and low volume PCBs and PCB Assembly



Brisbane based Iconic PCB locally manufactures and assembles printed circuit boards, whether for prototypes or for small production runs.

Iconic PCB has the ability to rapidly deliver electrically tested PCBs. Iconic PCB also manufactures multilayer boards.

The PCBs are supplied as brass boards or fully finished in green solder mask, white overlay and immersion silver.

Recent introduction of a very competitively-priced low volume rapid in-house stencil and SMT assembly process augments the overall capability. Obtaining prototype PCB/PCBA product from Iconic PCB ensures your IP remains within the Australian legal framework.

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PCB Designing and Manufacturing Tips - straight from the horse's mouth!

Most decent electronics engineers can design a half-decent Printed Circuit Board. But few understand what happens when they send their PCB file off to the manufacturer. There are many traps that most wouldn't know about, let alone consider. We asked Tejas Shah, the Business Development Manager of major Australian/New Zealand PCB supplier QualiEco Circuits, to give us some tips (with examples) from the manufacturing side.

PCB designers are often confused as to what manufacturers need to turn their masterpiece into reality. Without knowing the requirements of the manufacturer, mistakes are often made – and mistakes are always costly.

The manufacturer has great skill in interpreting what the designer actually wants but sometimes, they are left scratching their heads.

The adage "impossibilities done immediately, miracles take a little longer" springs to mind!

This article explains some basic PCB design/manufacturing concepts and ideas which will help expand your knowledge in not only PCB design but how your choices affect cost of efficiently manufacturing PCBs.

How to design a manufacturer-friendly PCB

Every manufacturer has a CAD/CAM department, where your PCB design is checked thoroughly before it goes in final production.

An EQ (Engineering Query) may be raised if the CAM engineer has any doubts. This process not only increases manufacturing lead time but can create confusion if there are many queries to resolve.

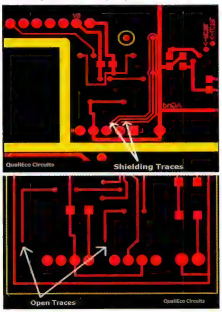
To-and-fro communication may also annoy you if queries are not handled professionally by the CAM engineer.

The million dollar question is – Is it really possible to design query-free PCBs?

Yes, it is possible, if some simple rules are followed throughout the design phase. A few examples that I am going to discuss here will certainly help you achieve this.

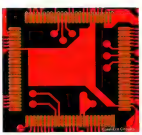
Shielding or open tracks

If you use shielding tracks or open tracks for antennas, please mention this clearly. CAM engineers normally catch such tracks and may result in a query.



Inter-track gaps

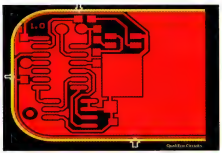
You should have at least 2 to 3mil (0.05 to 0.076mm) gap between two adjacent solder mask openings. A query would most likely be raised if the gap is smaller.



Tracks too close to cut lines

If any of your copper area or tracks are close to cut lines, the CAM engineer might ask your permission to shave copper to avoid cutting into it during routing or v-cut.

If you allow 0.3mm gap for routing and 0.4-0.5mm gap for v-cut, it would be considered a safe distance.



Multilayer PCB design

If you are designing a multilayer PCB, please provide a detailed layer stack-up, if you have any special requirements . Remember – there is more than

PCB FEATURE

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one way to build a structure and every manufacturer can prepare the layer stack up differently, based on the stock they carry for prepreg and core.

Plated holes

If your design file requires any holes to be plated, please provide copper pads on both sides. If the CAM engineer leaves the design unchanged, there could be plating issues, so you will most likely be asked for permission to add copper pad or, if you change your mind to non-plated hole, to isolate copper.

Mating PCBs

If your project requires one PCB to be inserted in another PCB (ie, mating PCBs), always consider both laminate thickness tolerance (±10%) and routing tolerance (±0.1 to 0.2mm) before designing slots

Surface finish considerations

You need to choose the surface finish very carefully. HASL is a default finish for most PCB manufacturers. If your product requires RoHS compliance, you can choose either lead-free HASL or immersion silver/gold/tin finish.

As a rule of thumb, if the minimum pitch of your SMD components is 0.5mm or lower, it is strongly advisable to choose immersion silver/gold/tin finish.

A word of caution: immersion silver finish PCBs need to be used within 2.5 to 3 months of the date of manufacturing. Silver finish demands great care in packing and storage.

Technical specifications

It is best practice to provide basic technical specifications in one of your layers. Some manufacturers do not send a detailed technical confirmation report and assume lot of technical parameters to their own standard, which may not be same as your expectations.

Communication is extremely critical for PCB manufacturing and one little misunderstanding could cost a fortune.

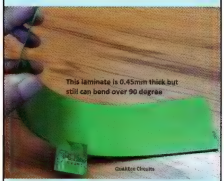
What makes a PCB expensive?

If you know what specifications are standard, you can make the maximum out of your design. Unfortunately, specifications differ from manufacturer to manufacturer – there is no "standard" specification.

The table below shows what QualiEco Circuits considers standard/non-standard features. Standard features result in the lowest cost PCBs. Non-standard features can of course be achieved but will result in a more expensive board.

Some interesting facts – Did you know this?

1. Rigid PCBs can be made as thin as 0.25mm. It means you can use it like a flexible PCB in certain cases. It is not a perfect replacement but if your aim is only to achieve little bit of flexibility, this is not a bad idea!



2. If you are designing a panel (ie array) of PCBs for pick and place assembly, you can get away with panel strip on only two longer sides of the panel by wisely placing break off tabs. Tab and hole sizes and positions are extremely important.

You can save up to 20% of unit price by intelligently designing your panel structure. For high volume manufacturing, it is indeed a huge saving!

A smart PCB manufacturer can study your component reference to judge required mechanical strength of the panel before suggesting an optimum panel structure.

PCB Specifications	QualiEco - Standard	QualiEco - Non-Standard
Laminate thickness	0.8mm to 1.6mm	0.4mm, 2.0mm & above
Copper thickness	1oz (35µ)	2oz and above
Via hole size	0.25mm and above	>0.1mm & <0.2mm
Track width/spacing	5mil (0.127mm) and above	>3mil (0.076mm) & <5mil (0.127mm)
Solder mask colour	Green, Red, Blue, White, Black	Red, Blue, White, Black (for high volume)
Overlay colour	White, Yellow	Yellow (for high volume)
Surface finish	Leaded or Lead-free HASL	Immersion silver/gold/tin, OSP
High Tg laminate	Tg 130°-135°C	Tg 150°-180°C
Peelable solder mask	No	Yes
Impedance control	No	Yes
Blind/Buried via	No	Yes
No "X" out panels	No	Yes
Via tenting	Using solder resist (not guaranteed 100%)	100% guaranteed
Via plugging	Using HASL (not guaranteed 100%)	100% guaranteed (silicon plugging)
Gold finger	No	Yes
Edge connector	No	Yes
Edge bevelling	No	Yes
Plated rout/PTH cut out	No	Yes
Countersunk hole	No	Yes
Jump scoring	No	Yes

Lintek has 27 years experience in Manufacturing PCBs in Australia

The PCB manufacturing industry has certainly changed over Lintek's 27 year involvement. To survive in this industry is not easy; your customer service, quality and knowhow must be second to none – local clients know that they are paying a premium and they don't need too many excuses to move offshore.

The 'heavyweights' of the 1980s and 90s have all but disappeared – or have moved higher up the food chain where they can value-add by providing turnkey solutions.

For Lintek, a 100% Australian manufacturer, the trick has been to try to stay nimble, dynamic and quick to respond. Developing good customer relationships and educating designers about the process complexities we encounter is paramount to our survival. They find that the best clients 'Design for manufacture' and are willing to modify their designs if it improves quality, consistency and price.

There is always a compromise between price and performance as higher quality dielectrics cost more, can be more difficult to process and manufacturing times are longer due to tighter process controls. Having an in-depth understanding of material behaviour over many years of processing exotic laminates gives their engineers the confidence to take on the most complicated projects, many of which their clients find difficult to source anywhere else. Knowing your 'sweet spot' is extremely important when taking on the rest of the world – having a technological advantage certainly helps.

R&D is extremely important to Lintek as it helps the company stay in touch with industry trends. The continuous miniaturisation of parts can leave you falling behind the pack very quickly and new opportunities become more difficult to find.

Driven by industry demands, Lintek is currently developing a number of new capabilities. One of these is to develop 'via-in-pad' technology around vacuum metalisation. This will enable the formation of copper-filled 'microvias' laser-drilled down to copper capture pads on multilayer PCB stacks. The copper-filled vias will simplify the assembly of BGA devices down to 0.4mm pitch and will be a first for Australia.

To help develop these capabilities, Lintek has been successful in receiving funding for this project through DMO under the PICIP (Priority Industry Capability Innovation Program).

The successful application for funding is testament to the critical role they play in supporting key defence suppliers. They are also working with the team from DIIC (Defence Industry Innovation Centre) to take business to the next level. Their understanding of business and government assistance available, along with training and awareness programs, has been a great help. Since their involvement with DIIC Lintek have joined SCIP (Sustainable Continuous Improvement Program or SC21), have become more active in the GSC (Global Supply Chain) and are working on implementing 'lean management' practices.

Finally, Lintek would also like to thank Andrew Pollock and his team at the SMCBA, they do a great job and offer an invaluable service to the Australian electronics industry.

LINTEK PRINTED CIRCUITS

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Incorporated in 1986, Lintek is a quality Australian manufacturer of Microwave printed circuit boards. Lintek's patented High Vacuum Deposition process enables the production of extremely accurate microwave circuit features on a wide variety of conventional and exotic substrates including precision milled metal backed carriers. High bond strength to PTFE and minimal side wall undercut are two key features synonymous to Lintek's process. This innovative process allows Lintek to provide PCB's for the latest high frequency commercial or military designs as well as the standard FR4 Single sided, DSPTH and Multilayer circuit boards.

Unrivalled Accuracy

i) Lintek's process requires significantly less etching to remove a very thin 1-2 micron vacuum deposited copper seed layer instead of the standard 18 microns copper base layer used on Electroless copper processes, thus eliminating undercut and ensuring the repeatability of:-

a. very fine track and spaces.
b. accurate copper features and filters.
c. near perfect side wall resolution.
d. superb impedance control.

e. High bond strength to exotic substrates

ii) Plated through holes are stronger and more reliable due to the same amount of copper being deposited in the hole barrel as on the surface. This is particularly important on PTFE materials, which have a large thermal expansion in the Z direction.

iii) The elimination of Sodium etching that is normally used on PTFE materials, this saves time, cost and our environment.

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PCB FEATURE

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Understanding C

How, When, Where and Why they're used

You may not realise it but many, if not most, PCBs these days have a conformal coating. But what is that – and what is its purpose?

Conformal coatings are thin polymeric films which cover and protect solder joints, the leads of electronic components, exposed tracks and other metallized areas on PCBs from corrosion.

Humidity, condensation, salt-spray, corrosive gases or a combination of all of these activate the start of the corrosion process, which can be accelerated by residues from soldering and other assembly processes prior to coating.

There are many conformal coating chemistries available and each have their own benefits and drawbacks. Conformal Coatings are available in solvent-based, water-based and 100% active materials (nearly everything that is applied in liquid form is converted into solid protective coating), as well as vapour deposited coatings.In these, gases are mixed in a vacuum, where they are polymerized and deposited onto the surface of the PCB as a protective film.

The primary benefits and disadvantages of the different chemistries available can be summarised as follows:

Coating Standards

Most conformal coatings are either qualified to MIL-I-46058C or meet the requirements of the closely related IPC-CC-830B specifications. In addition they may be recognised by Underwriters Laboratories, either as a permanent coating, in which case the flammability of the coating is assessed to UL94V0, or as a conformal coating, where the electrical properties will be assessed as part of the UL746E standard.

The actual protective capability of the coating in the end use environment is of greatest concern to the user.

Corrosion

Corrosion is a complicated electrochemical process with a variety of potential mechanisms and causes, well beyond the scope of this article. However, in the vast majority of cases, there are three requirements that must be fulfilled in order for corrosion to proceed, as shown above right.

In order to prevent the possibility of corrosion, it is necessary to remove one of the pre-requisite conditions.

The choice of metals is limited to those used in the solder and solder finish chemistries (which are often dissimilar) and there will always be areas of potential difference in an operating circuit. Cleaning can help remove ionic species, but cannot prevent the re-deposition of ionic species from the operating environment.

Conformal Coatings help prevent the formation of electrolytic solutions by acting as moisture barriers. The coating must have good adhesion to the substrate to prevent delamination. Once the coating is delaminated, moisture can eventually collect in this 'pocket' and form an electrolytic solution with any pre-existing ionic contamination. This is the reason that cleaning prior to conformal coating is recommended.

Application Process

In order to obtain the maximum levels of protection available from the particular chemistry, two key criteria must be fulfilled:

1. The coating must display excellent adhesion to the substrate in question under both dry and highly humid or damp conditions to prevent delamination.

2. The coating must fully cover the exposed metal surfaces in order to be effective as a moisture barrier.

Thus, selecting the 'correct' conformal coating is merely the first stage in the protective process. Perhaps of greater importance is the preparation prior to coating (eg cleaning) and the actual ap-

Coating Type	Primary Advantage(s)	Primary Disadvantage(s)
Solvent-Based Acrylic	Ease of use Fast Drying Good general purpose protection Easy rework	Poor solvent-resistance High Volatile Organic Compound emissions Adhesion unpredictable
Solvent-Based Urethane	Ease of use Better chemical resistance	High Volatile Organic Compound emissions Harder to rework
Silicone Chemistry	Excellent High and Low Temperature performance Excellent protection against liquid water Low odour, easy to use	Porous to moisture vapour Less protection against corrosive gases Silicone cross-contamination Can have high VOC emissions
UV curable	Low VOC emissions Fast-curing Reduced Work In Process (WIP)	More sophisticated process Harder to rework

NFORMAL COATINGS:

by Phil Kinner
Technical Director, Electrolube

plication process itself. Conformal coating materials are not intelligent; they go where they are placed.

Most materials will tend to slump away from sharp component edges, leads and solder joints due to gravity, and this behaviour can be made worse by longer drying times and also by baking, if the initial viscosity drop is greater than the increase due to solvent evaporation. It is also extremely difficult to achieve good coating coverage on the backsides of leads. Understanding and controlling this behaviour, and its effect on the conformal coating coverage, will be key to the performance of coated assemblies operating in harsh environments.

Therefore, the process by which the conformal coatings are applied, and the workmanship and control within that process, will have the greatest influence on the success or failure of that particular coated assembly.

Conclusion

Understanding that the conformal coating can only protect the surfaces to which it is applied with perfect coverage, and that voids, bubbles and cracks in the coating are likely to present a high-probability corrosion initiation site, is a major step towards developing a reliable product.

Choosing a suitable conformal coating chemistry that can withstand the expected environmental challenges whilst still yielding acceptable performance levels is the next step.

But ensuring that the material can be combined with an application process that gives a suitable level of defect-free coverage, is consistent, repeatable and yields the required levels of performance is the ultimate step towards ensuring a high-reliability product.

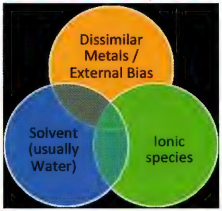

Fig.1 – required conditions for corrosion of a printed circuit board.

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For further information contact Control Devices on stand D29 at Electronex 2014, or via www.controldevices.net Tel 1800 266 876.

Crazyflie – DIY Nano Quadcopter

Ever wanted a development kit that flies? Well now you can! The Crazyflie is an open source nano quadcopter kit designed for flexible development and hacking. It's among the smallest in the world, weighing only 19 grams and measuring 90mm motor to motor.

There is a 2.4GHz radio chip onboard which is used for receiving commands and sending telemetry data back to the USB RF Module (included) on the host computer.

All you need is a PC compatible joystick and micro-USB cable for charging (both sold separately).

This nano quadcopter was designed with development in mind and has an expansion header and backed with good software support. The platform is open source, which means schematics, firmware and source code are available for customisation, or even just to check out how it ticks.

This kit requires partial assembly, some soldering skills and is not for absolute beginners.

Contact: Core Electronics Pty Ltd Website: www.core-electronics.com.au

Taking the burden out of prototyping

Embedded Logic Solutions Pty Ltd has been a supplier of quality tools for embedded system development and prototype assembly for over ten years.

Teaming up with leading names like LPKF and Number One Systems, the company provides cost effective in-house PCB production and SMT board assembly solutions for prototype applications.

Understanding the fast turnaround importance for PCB prototyping and the challenges faced with outsourcing or in-house manual component placement, Embedded Logic Solutions now distributes the complete range of SMT assembly solutions, from German manufacturer, Mechatronic Systems, offering customers an end-to-end, cost effective prototyping line, in-house.

Going beyond boxed solutions, the company is considering a PCB routing and assembly service for proof-of-concept and prototype boards.

The service, soon to start as a pilot project, will target companies, professional designers and amateurs and will include component sourcing if required. For further information on this service and other prototyping solutions, please contact us by phone or via website.

Embedded Logic Solutions Pty Ltd are on stand D12 at Electronex 2014; otherwise you'll find them Suite 2, Level 3 144 Marsden St, Parramatta NSW 2150 Tel: (02) 9687 1880 Web: www.emlogic.com.au

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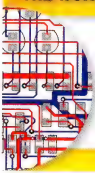

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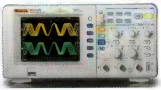
Oscilloscopes



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PCB ElectronEX FEATURE

Need solder paste stencils?

Mastercut Technologies now manufactures DEK Stencils in Australia

Mastercut Technologies is now licensed by DEK Singapore to manufacture DEK VectorGuard stencils, as well as supply new frames.

The DEK VectorGuard Framing System is an automatic tensioning system for solder paste stencils. It eliminates the need for complex alignment procedures and is independent of traditional pneumatic assistance processes.

The stencils feature an extruded aluminium guard, which is securely attached to the edge of the foil using interlocking plastic corners. Providing accurate and automatic tensioning, it takes only seconds to mount a foil into the VectorGuard frame.

Mastercut will be launching the DEK VectorGuard Framing System in Australia, at Electronex in September this year. This comes after the launch of the LPKF ZelFlex System in 2013, also by Mastercut.

With over 20 years experience, Mastercut is the only solder paste stencil manufacturer in Australasia and pride themselves on providing the highest quality stencils and fast turnaround.

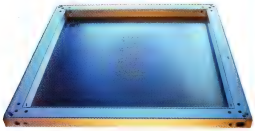
Mastercut Technologies Managing Director, Mr Jim Cove, explained, "All of our stencil customers demand guaranteed high precision and fast delivery, in order to meet their forever tight deadlines".

"We use German laser cutting technology which has been specifically designed to manufacture stainless steel SMD solder paste and adhesive stencils, for a consistent high quality cut and excellent paste release", Mr Cove Said.

Both VectorGuard and ZelFlex systems provide superior tensioning and result in a reduction of stencil storage space by up to 75% compared to traditional mesh mounted stencils, as well as being more cost effective to freight.

Visit Mastercut at stand A15 at Electronex in Sydney, 10-11th September to see both the VectorGuard and ZelFlex frames first hand.

Alternatively, you can contact Mastercut Technologies at 22 Leda Drive, Burleigh Heads QLD 4220, Tel. (07) 5576 1900; website www.mastercut.com.au



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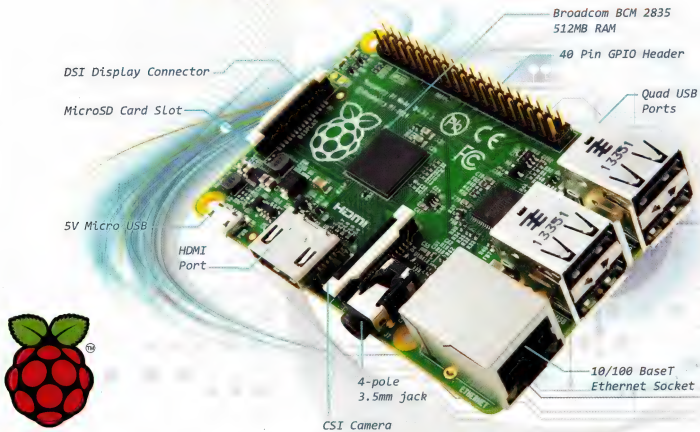

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PCB ElectroneX FEATURE

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Soltronico is a new Australian company providing a unique blend of high quality, small volume manufacturing and custom jobs that larger manufacturing plants ignore. Being local (their plant is located near Newcastle, NSW), customer service is their top priority.

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Satcam's range of Quick Circuit machines will take your computer PCB design and turn it into a finished prototype faster than it takes a courier to deliver one from a bureau!

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A typical 300 x 300mm single-sided board will take about an hour to produce. Compare that with traditional (photo) methods which don't have the flexibility of the Quick Circuit Mill.

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PCB ElectronX FEATURE

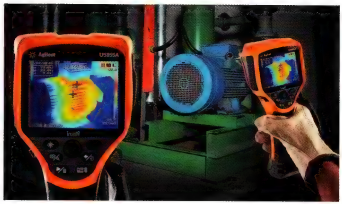
Keysight Technologies' New U5855A Handheld Thermal Imager

With the shift toward predictive maintenance, the U5855A TrueIR thermal imager allows engineers to safely and efficiently identify potential faults without shutting down the systems or disrupting the productivity of an industrial plant.

The U5855A comes with Fine Resolution capability, which enhances the quality of thermal images by reconstructing the image based on multiple continuously captured infrared frames. This allows the U5855A to achieve an effective image resolution of 320 x 240 pixels from a 160 x 120 pixel detector.

With this feature, the U5855A provides four times more resolution than typical 160 x 120 thermal imagers. Together with a 4x digital zoom, the U5855A reveals finer details, especially when inspecting small cracks on industrial pipelines even from a distance.

The U5855A's light and ergonomic design allows engineers to comfortably use the thermal imager for longer periods of time and operate it single-handedly in tight



locations. Users can also easily change settings or access frequently used functions such as torch light and laser pointer, auto scaling or trigger with quick access buttons.

Keysight Technologies are on stand C11 at Electronex 2014. If the name Keysight Technologies doesn't ring any bells, you probably remember them by their old name, Agilent Technologies. Keysight Technologies Australia is on stand C11 at Electronex 2014; you can also contact them via their website, **www.keysight.com** or call 1800 629 485. Address is 679 Springvale Rd, Mulgrave, Vic 3170.

HAMEG Instruments now carry the Rohde & Schwarz name

Test and Measurement products from Rohde & Schwarz subsidiary HAMEG Instruments are now marketed under the Rohde & Schwarz logo.

The well-known brand name will help improve the international position of the economical, general-purpose T&M instruments from HAMEG, which are part of the joint Value Instruments portfolio.

Previously, all HAMEG products had a dual logo that included the company names Rohde & Schwarz and HAMEG. According to Roland Steffen, Executive Vice President and Head of the Test and Measurement Division, "In recent years, HAMEG has grown rapidly in Europe. Now we want to expand this growth to other regions. The best way for this to succeed is with the Rohde & Schwarz brand, which enjoys an outstanding reputation worldwide. This strategy clearly sets us apart from other suppliers."

Using the Rohde & Schwarz logo is also the logical continuation of the Value Instruments initiative, where the two companies' portfolios of reliable precision instruments in the entry-level price segment are marketed together under the Value Instruments label.

André Vander Stichelen, Managing Director of HAMEG Instruments, elaborates, "By changing the logo, we want to underscore the common bond between the two companies. The strategic focus of HAMEG will not change. We will continue to offer affordable, optimum performance T&M equipment."

The company HAMEG Instruments GmbH will continue to operate as an independent company under the umbrella of the Rohde & Schwarz group of companies. The two sites in Mainhausen and Chemnitz will be expanded.

For more information on Value Instruments, visit **http://value.rohde-schwarz.com** or call into the Rohde & Schwarz stand (D2) at Electronex 2014.

Altronics at Electronex

As well as releasing their all-new 2014/2015 product catalog at Electronex 2014 Altronic Distributros will also be showcasing a selection of their products, including the 'latest thing' – a 3D printer from Velleman.

Did you ever wanted to create your own prototype products in 3D? Did you dream that your 3D creations become real products?

This is your chance to make it happen with Velleman K8200 printer. It's a build-your-own 3D printer kit which can print objects up to 200x200x200mm using PLA or ABS filament 3mm plastic wire.

It's extremely fast, precise and reliable printer even when printing at higher speed. The K8200 is compatible with all free 'Rep Rap' software and firmware. It is made out of aluminium profiles and is easy to assemble; it leaves room for the user to freely alter the machine and modify it to their liking. The print bed is heated.

You can convert the Velleman K8200 to be used as a CNC machine or a Computerised PCB drilling machine. Create your own custom designed one-off PCBs, cut Acrylic shapes and do much more.

Check the Velleman K8200 out at Electronex, or for further information and assistance please call Altronic Distributors on 1300 780 999 or send an email to: sydwsale@altronics.com.au or refer to their web site, **www.altronics.com.au**

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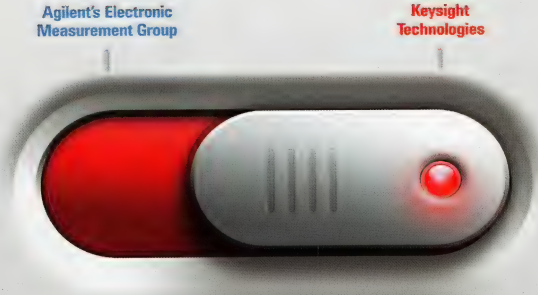

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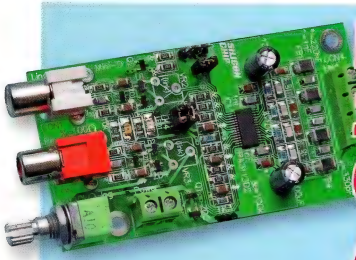
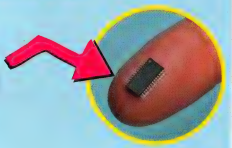


Mini-D Stereo 10W/Channel Class-D Audio Amplifier

This little chip can deliver a whopping 30 watts! With no heatsink!



Main Features

- Stereo or mono Class-D amplifier on a single, small PCB
- No heatsink required
- Low EMI
- DC power supply, wide operating voltage range
- Drives one or two 4-8Ω speakers
- Selectable gain
- On-board volume control
- RCA input sockets
- Shutdown mode
- Output short-circuit protection
- DC offset protection
- Over-temperature shutdown with auto resume
- Selectable output power limit with soft clipping
- Low quiescent current
- Reversed supply polarity protection
- Input signal overload protection
- Power and fault indicator LEDs
- Under-voltage and over-voltage lock-out

This tiny Class-D amplifier module can work in two modes. In stereo it can deliver more than 10W per channel or you can connect its output channels in parallel to deliver more than 25W into a single speaker. It is up to 91% efficient, with selectable gain, volume control and other features such as a low-power shutdown mode and over-temperature, over-current, short circuit and speaker protection.

By NICHOLAS VINEN

HOW CAN A CHIP this small deliver so much power? And how can it deliver so much power without needing a big heatsink? The answer to both questions is Class-D operation. It's a switching amplifier and its efficiency can be over 90%. High efficiency is also good if you want to run it from a battery since it will last longer. And if running from mains, you don't need a bulky power supply; a 1A plugpack should be more than adequate.

We published our first switching amplifier design, the CLASSiC-D, in November & December 2012. It's a powerful beast, able to deliver up to 250W into a 4-ohm load or 500W into an 8-ohm load (bridged) with low distortion. Lots have been built since its publication.

But while you may want the high efficiency of Class-D, the CLASSiC-D is simply too big and expensive for many applications where you only need a few watts of audio, perhaps running off a small battery – for busking, for

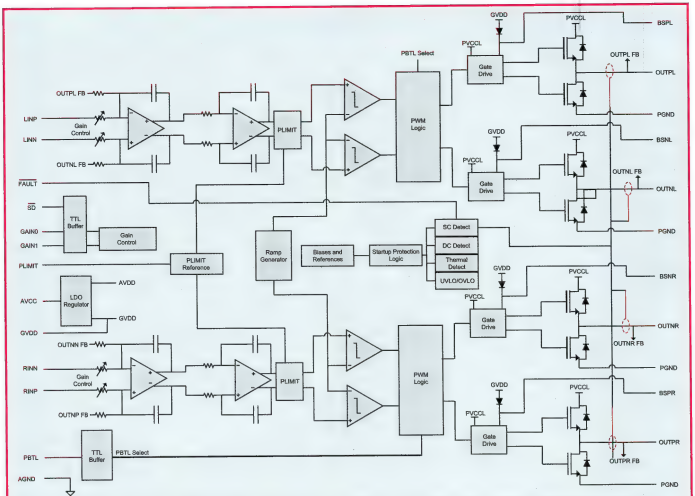


Fig.1: block diagram of the TPA3113D2 Class-D audio amplifier IC. The left & right channel differential inputs are buffered and fed to Schmitt trigger stages where they are compared against a ramp (triangle) signal. The resulting PWM signals are then fed to PWM logic blocks which then drive two bridge-mode stereo switching amplifiers.

example. Or say you want to build a pair of self-powered computer speakers. Whatever the reason, a few watts can go a long way.

That's where Mini-D amplifier module comes into its own. It's based on the Texas Instruments TPA3113D2 which contains two complete bridge-mode stereo switching amplifiers. It's so efficient that it doesn't need a heat-sink for normal program material; the PCB itself dissipates the heat.

Only a simple output filter is required to minimise the amount of RF interference generated by its switch-mode operation. This consists of just four ferrite beads and four ceramic capacitors, or eight components for the two channels. All the components are surface-mount types, selected so that they are straightforward to solder.

Because the Mini-D module's outputs are bridged, it has good power delivery even with moderate supply rails. With a 12V supply, it can deliver at least 5W per channel into 8-ohm speakers or 2 x 10W into 4-ohm loads. More power is available with higher supply voltages.

Unusually, the Mini-D can also operate in mono mode, with the outputs paralleled. This doubles its current capability, allowing more power into low-impedance loads, eg, 25W or more into 4Ω.

By the way, we've said this in the past but it bears repeating: while the output transistors in Class-D amplifiers spend most of their time either on or off, they aren't really 'digital' amplifiers. While there may be some digital circuitry involved, they still work on the principle of analog negative feedback to generate the correct output waveform for a given input signal.

Class-D amplifier operation

We won't go into the full theory of how a Class-D amplifier works but let's look at the functional block diagram of the TPA3113D2 IC (Fig.1) which is the heart of the circuit.

The two inputs are differential. Looking at the left channel, the signals are fed to LINP (in-phase) and LINN (ground/out-of-phase) at top left. The feedbacks from the switching outputs, OUTPL FB (positive) and OUTNL FB (negative), pass through low-pass RC filters internal to the IC and these four signals all go into a differential amplifier which performs this analog computation:

(LINP - LINN) x GAIN - (OUTPL - OUTNL)

The GAIN setting is determined by the state of two digital inputs, GAIN0 and GAIN1, which control the resistances in this part of the circuit to select an effective gain of 20dB, 26dB, 32dB or 36dB. The output of this differential amplifier then passes through another RC low-pass filter, to further attenuate

Parts List

1 double-sided PCB, code 01110141, 46 x 85mm
4 HI1812V101R-10 ferrite beads, SMD 4532/1812 (FB1-FB4) (element14 2292377)
2 PCB-mount switched RCA sockets, white & red (CON1-CON2) OR
2 2-way pin headers plus shielded cable, header plugs and chassis-mount RCA sockets
3 2-way mini terminal blocks, 5.08mm spacing (CON3-CON5)
1 3-way pin header, 2.54mm pitch (CON6)
3 shorting blocks
1 10kΩ dual gang 9mm log potentiometer (VR1) OR
2 10kΩ mini horizontal trimpots (VR2-VR3) OR
1 20mm length tinned copper wire or two component lead off-cuts
3 2-way pin headers, 2.54mm pitch (LK4-LK6)
3 tapped spacers with M3 x 6mm machine screws (optional, for mounting)

Semiconductors

1 TPA3113D2PWP Class-D Audio Amplifier IC, HTSSOP-28 (element14 1762987)
1 IRFML8244 N-channel Mosfet, SOT-23 (Q1) (element14 1857298)
1 BSS84 P-channel Mosfet, SOT-23 (Q2) (element14 1431318)
5 5.6V zener diodes, SOT-23 (ZD1-ZD5) (element14 1431238)
2 BAT54A dual Schottky diodes, SOT-23 (D1,D2) (element14 2114869)
1 high-brightness green LED, SMD 3216/1206 (LED1) (element14 2217905)*
1 high-brightness red LED, SMD 3216/1206 (LED2) (element14 1226389)*

Capacitors (all SMD 3216/1206 unless stated)**

2 100µF 25V low-ESR radial electrolytics
7 4.7µF 25V X7R ceramic (element14 1828835)
6 220nF 50V X7R ceramic (element14 1327724)
8 1nF 50V NP0/C0G ceramic (element14 2280692)
4 330pF 50V NP0/C0G ceramic (element14 3606090)

Resistors (all SMD 3216/1206 1%)**

9 100kΩ (element14 1811974)
2 10kΩ (element14 1811973)
2 100Ω (element14 1632521)
5 10Ω (element14 1591420)
2 4.7Ω (element14 2142059)
2 0Ω (element14 1632520) (LK1-3)

* or use 2 x 2-pin headers with off-board LEDs
** SMD 2012/0805 size parts can also be used

the switching artefacts in the signals, and then into a differential buffer.

During normal operation, with the output correctly tracking the input (after gain is taken into consideration), the output of these amplifiers will be virtually nil, ie, the two differential lines will be at the same potential. Any deviation from this state means that the amplifier output must swing one way or the other.

The buffered signal passes through the PLIMIT block which allows an external voltage to limit the maximum output swing, for speaker overload protection. The signals then pass into a pair of Schmitt-trigger comparators where they are compared against a ramp (triangle) signal, generated by an internal oscillator.

This is a common method for producing PWM (pulse width modulation), typically used in motor control circuits. The main difference here is that the operating frequency is much higher; around 310kHz. This is necessary to allow accurate reproduction of audio signals up to 20kHz.

PWM output

These signals then pass through the PWM logic to the Mosfet gate drivers and then the totem-pole output stages, consisting of N-channel Mosfet pairs.

This chip uses a 'centre-aligned' or 'dual-ramp' PWM, a different modulation scheme to that used in many other Class-D amplifiers. This is shown in Fig.2 and is possible because the TPA3113D2 always operates in bridged mode. In the quiescent condition, both outputs are driven in-phase with a 50% duty cycle (top of Fig.2) and this results in no current flowing in the speaker(s) or filter at all.

To drive the output positive, the duty cycle of the positive output is increased while the negative output duty cycle decreases (middle of Fig.2). This is done by shifting both the leading and trailing edges of both waveforms. Since none of these edges line up, this spreads RF emissions out, making them easier to filter. To drive the output negative, the reverse condition occurs (bottom of Fig.2).

Since the output transistors are N-channel Mosfets, a supply above the positive rail is required for the upper gate drive. This is generated by four 220nF capacitors between the OUTPL & BSPL terminals, OUTNL & BSNL etc. When the respective output is low, its capacitor charges through an internal diode from GVDD (~7V) and when the output goes high, the capacitor charge maintains the associated boost pin 7V above that output, sufficient to keep the upper Mosfet conducting.

The block diagram also shows the protection circuitry, including short-circuit detection, output DC offset detection, high temperature detection and under/over-voltage lock-out. Should any of these fault conditions occur, the output drivers are all switched off. The over-temperature cut-out kicks in when the die temperature hits 150°C and operation resumes once it has dropped by around 15°C.

When the chip is running in mono mode, as set by the PBTL input pin, the PWM logic is modified slightly so that OUTPL and OUTNL carry an identical signal. At the same time, OUTPR and OUTNR are both driven with the same out-of-phase PWM signal, allowing the pairs of outputs to be paralleled.

Speaker wires

Because 'centre-aligned' PWM is used in this chip, only a very simple output filter is required to minimise the amount of RF interference generated. This consists of just four ferrite beads and four ceramic capacitors. The data sheet states that the ferrite bead output filter is sufficient for twisted speaker wires up to 1.2m long. We imagine that standard figure-8 speaker wires should also be OK, given that the conductors are in close proximity.

If you want to use longer speaker leads or are particularly concerned about radio interference, you can add

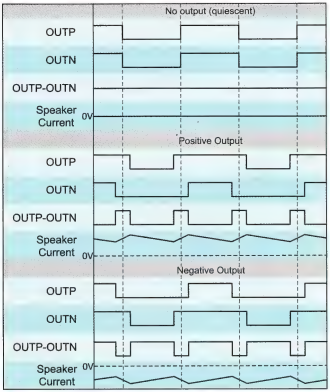


Fig.2: the quiescent (top), positive output (middle) and negative output (bottom) signal waveforms for the TPA-3113D2 Class-D audio amplifier IC.

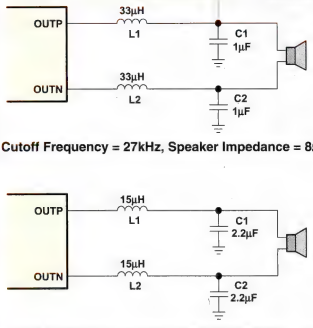


Fig.3: an external LC filter can be added if long speaker leads are to be used, with the filter component values selected according to the speaker impedance. These two diagrams show the recommended values for 8-ohm and 4-ohm loads.

an external LC output filter. This could be wired externally to the board, ie, between the output terminals and speakers. Note that you would need to keep the components relatively close and run some connections to a PCB ground point.

One disadvantage of this approach is that the filter component values must be selected based on the speaker impedance. Also, the inductors must handle the peak load current (up to 4A in some cases) without saturating. The recommended filters for 8-ohm and 4-ohm loads are shown in Fig.3. Note that an LC filter may also give improved efficiency.

Speaker impedance

For supply voltages up to 15V, the unit can drive speakers with nominal impedances from 4-8Ω. Above 15V, however, it isn't recommended to drive 4Ω speakers. Plenty of power for 4Ω loads is already available at supply voltages below 15V anyway.

To drive 4Ω speakers from a supply above 15V, it's necessary to run the Mini-D in mono mode; more on that later. To drive two speakers in this mode, you will need to build two boards but in exchange for that, you get more power and higher efficiency.

Circuit description

The full circuit is shown in Fig.4. All the real work is done by IC1. The left & right channel input signals are applied to RCA connectors CON1 and CON2. Alternatively, pin headers may be fitted in their place for connection to chassis sockets or another board. From this point on, we shall refer to the operation of one channel only.

The signal first passes through a low-pass RF-rejecting filter, comprising a 100Ω series resistor and 1nF ceramic capacitor. Both the signal and ground pins are then AC-coupled to the volume control potentiometer (VR1) via 4.7µF ceramic capacitors. The signal ground is also connected to power supply ground via a 4.7Ω resistor, taking advantage of the differential inputs provided by the IC.

This 4.7Ω resistor reduces the chance of hum being injected into the signal due to the common input grounds.

The volume control potentiometer is either a dual-gang log pot (VR1) or two horizontal trimpots (VR2 & VR3), the latter used for a pre-set volume level. If you don't need volume control at all, simply link out VR2 and VR3. Regardless, the wiper of each pot goes to the non-inverting input for each channel (pins 3 & 12) while the bottom (AC-grounded) end goes to the inverting inputs (pins 4 & 11).

The TPA3113D2 can handle a strictly limited voltage range at each input pin of -0.3V to 6.3V so we have added protection components to limit these voltages when the power is off or in case a high level signal is applied (which is common when plugging and unplugging RCA leads).

These parts consist of 5.6V zener diodes (ZD1-ZD4) and parallel Schottky diodes (D1 & D2) between each input and ground. The zener diodes take care of clamping positive signal swings while the Schottky diodes clamp negative excursions more effectively.

The outputs of IC1 pass through the recommended output filter, consisting of four large ferrite beads (FB1-FB4; HI1812V101R-10) and four 1nF C0G ceramic capacitors. C0G capacitors have a very low temperature coefficient (±30ppm) but also low ESR (equivalent series resistance) and ESL (equivalent series inductance); just what we need to suppress sharp voltage spikes.

Specifications

Supply voltage: 8-25V DC
Quiescent current: typically <40mA active, <2mA shutdown
Speaker impedance: 6-8Ω; 4-8Ω in mono mode or in stereo with up to 16V supply
Continuous output power: 2 x 5W or 1 x 10W (12V, 8Ω)
Peak output power: 2 x >15W or 1 x >30W (thermally limited)
THD+N: typically <0.1%; see Figs.6 & 7
Signal-to-noise ratio: 100dB
Frequency response: 20Hz-20kHz ±1dB; see Fig.9
Efficiency: up to 82% (stereo), 91% (mono)
Gain: 20dB, 26dB, 32dB or 36dB
Under-voltage lockout: ~7.5V
Output offset voltage: typically within ±1.5mV
Power supply rejection ratio: typically -70dB
Switching frequency: ~310kHz

We have also added snubbers, consisting of 330pF C0G ceramic capacitors in series with 10Ω resistors, from each output to ground. They are actually wired to the boost supply pins but these are AC-coupled to the outputs via much larger 220nF capacitors so the effect is the same. These reduce radiated EMI further by limiting the output voltage slew rates.

We have used a 1:1 voltage divider between GVDD (pin 9; ~7V) and ground, with a 4.7µF filter capacitor, to set PLIMIT (pin 10) at 3.5V. This limits the output amplitude to about ±11V (22V peak-to-peak). Thus it will only limit the output power with a DC supply over 20V.

If you are trying to get the maximum possible power from the chip at 24V, you could reduce the upper divider resistor to 47kΩ but in most cases it won't make much difference; the 'soft clipping' provided by this limiter may have some benefits in reduced treble artefacts if you are going to drive the amplifier that hard anyway.

Other features

100kΩ pull-ups on GAIN0 and GAIN1 allow links LK4 and LK5 to define these input states. A table in the circuit diagram shows the possible settings. With a gain of 20dB (10x), input sensitivity is 425mV RMS for a 12V supply and 850mV RMS for a 24V supply. With the gain set to 36dB (63x), input sensitivity is 67mV RMS for a 12V supply and 135mV RMS for a 24V supply.

The unit can handle signals up to at least 3V RMS. For line-level signal sources such as CD players, 20dB of gain should be plenty, so most constructors should stick with that.

The FAULT output (pin 2) is connected to pin 1 on CON6, which can go to a microcontroller pin (but with some provisos, see below). It goes low if the IC detects that an output is short-circuited or there is a DC offset fault. The FAULT signal also switches P-channel Mosfet Q2 via a resistive divider (which ensures that Q2's gate is not over-driven). If there is a fault, Q2 switches LED2 (red) on. This can either be an SMD LED mounted on the board or an external LED wired up via pin header CON8.

The shut-down input (pin 1) is also connected to CON6 (at pin 2) and is pulled up by a 100kΩ resistor so that the amplifier will power up automatically. If pulled to ground, the amplifier shuts down and only draws about 250µA. However, that doesn't include the current for LED1 and the various pull-ups, which increase total shut-down current to around 2mA.

If a shorting block is placed on LK6 and an output short circuit is detected, once the short has cleared, the amplifier will automatically resume operation. Otherwise, short circuit faults are 'latched' and the unit remains off (with LED2 lit) until the power is turned off and back on again.

Over-temperature faults are automatically cleared and LED2 will not light if IC1 overheats; rather, output will simply cease and then resume once it has cooled.

Power LED1 (green) can either be an on-board SMD LED or it can be mounted off-board via pin header CON7. Supply current for LED1 and LED2 is around 1-2mA, so high-brightness types should be used.

Power supply

The 8-25V DC supply (from a battery, plugpack or power 'brick') comes in via terminal block CON3, with Mosfet Q1 providing reverse polarity protection. If the supply polarity is correct, Q1's gate is pulled positive via the 100kΩ resistor. This switches Q1 on, so current from the circuit can flow back to the supply ground.

However, if the supply polarity is wrong, Q1's gate will be pulled negative relative to its source and Q1 will remain off, so no ground current can flow and the circuit is protected. Q1's drain-source voltage is rated at 25V, so as long as the DC supply is within the specified range, this will be sufficient to block the supply voltage.

Zener diode ZD5 limits Q1's gate voltage to a safe level when the supply voltage is above 20V.

There's little else to the power supply other than the bypass capacitors, which consist of one 100µF electrolytic, one 220nF X7R ceramic and one 1nF C0G ceramic for each pair of power V_{CC} pins, ie, PVccL (pins 27 & 28) and PVccR (pins 15 & 16). The analog supply, AVcc, is at pin 7 of IC1 and has a 10Ω/4.7µF RC low-pass filter to remove switching noise.

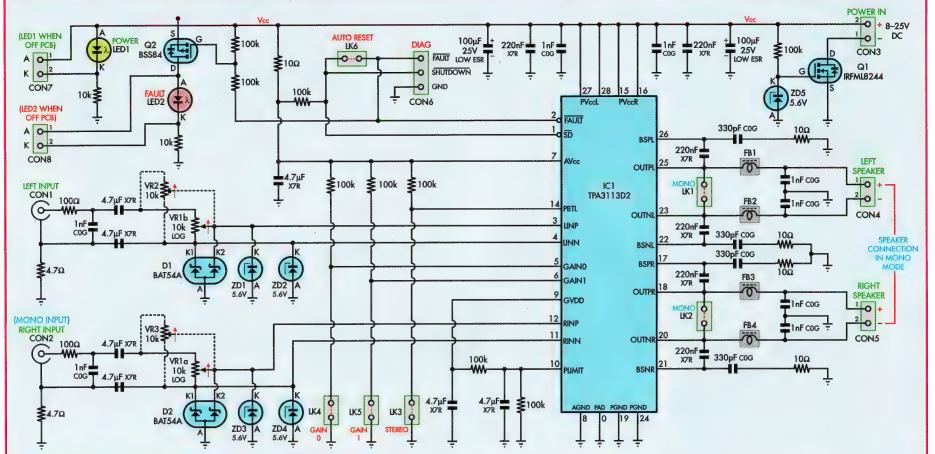
IC1's internal Mosfet gate supply regulator has a 4.7µF output filter capacitor at pin 9 (GVDD).

Mono (parallel) mode

To operate in mono mode, LK1 and LK2 are fitted and LK3 is left out. The speaker in then connected between CON4 and CON5 as shown on the circuit diagram. LK1, LK2 & LK3 are 0Ω surface-mount resistors.

In this case, you can also omit FB2, FB3 and the two associated 1nF capacitors. Plus you can omit CON1 and its associated components as the mono signal is fed into the right input (CON2).

Note though that you will only get more power in mono mode (also known as PBTL or Parallel Bridge-Tied Load mode) with a low-impedance speaker, eg, 4Ω. This is because with higher speaker impedances, you will run into clipping before the maximum



LK4	LK5	GAIN
IN	IN	20dB
IN	OUT	26dB
OUT	IN	32dB
OUT	OUT	36dB

STEREO/MONO MODE LINKING			
MODE	LK1	LK2	LK3
STEREO	OUT	OUT	IN
MONO	IN	IN	OUT

*EITHER DUAL LOG POT VR1 OR TRIMPOTS VR2 & VR3 ARE FITTED; THE LATTER FOR PRESET VOLUME

NOTE: FB1–FB4 ARE HI1812V101R-10 SMD FERRITE 'BEADS' (1812 SIZE, 8A RATED)

SC CSD14 'MINI–D' 10W x 2 CLASS D AMPLIFIER

Fig.4: the complete circuit diagram of the Mini-D 10W x 2 Class-D Amplifier. The audio input signals are fed in via CON1 & CON2, filtered and fed to the LINP (pin 3) and RINP (pin 12) inputs of IC1 via dual-gang volume control VR1. The amplified outputs appear at pins 25 & 23 (left channel) and pins 18 & 20 (right channel) of IC1 and these drive the left and right speakers via ferrite bead/capacitor filter networks. Links LK1-LK3 select either mono or stereo operation (see table), while links LK4 & LK5 set the gain. Mosfet Q1 provides reverse polarity protection, while Mosfet Q2 drives the fault indicator LED (LED2).

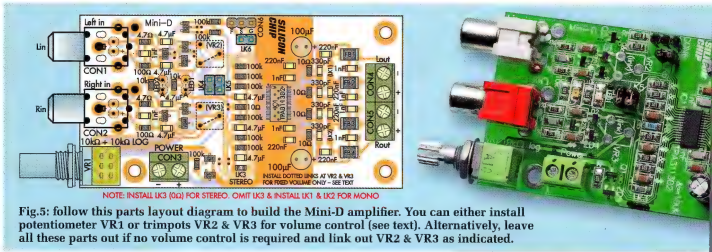


Fig.5: follow this parts layout diagram to build the Mini-D amplifier. You can either install potentiometer VR1 or trimpots VR2 & VR3 for volume control (see text). Alternatively, leave all these parts out if no volume control is required and link out VR2 & VR3 as indicated.

output current becomes the limiting factor. With a 4Ω speaker at 15V in mono mode, output power is up to 30W, which is pretty good! Even if you don't need the extra power, it's preferable to use the module in mono mode as it improves efficiency.

24V battery operation

Since the maximum recommended operating supply voltage for IC1 is 26V and there are a number of 25V-rated components in the circuit, we don't recommend running directly from a 24V battery. In theory, if you increased the voltage ratings of the 25V capacitors and Mosfet Q1, you might get away with it as the absolute maximum specified for IC1 is 30V. But it's outside the recommended operating voltage range so we don't suggest doing that.

A better option is to use a 24V low-dropout pre-regulator, eg, by placing a 12V zener diode in series with the ground pin of an LM2940CT-12 regulator to 'jack it up' to 24V. You will need appropriate input and output filter capacitors. The LM2940 is only rated at 1A but is unlikely to run into current limiting during normal operation. It may need a small heatsink though, as it could dissipate up to 5W.

PCB layout

Being a switching amplifier, instantaneous currents can be high and the voltage rise/fall times are very short, so the the design of the PCB has been quite rigorous. We also wanted to keep switching noise away from the analog circuitry. Bypass capacitors need to be near IC pins and the output filter must be kept tight for maximum EMI suppression. There are also thermal considerations, given that the amplifier IC uses the board as a heatsink.

We've placed ground planes on both the top and bottom of the board immediately under IC1 and fanned them out to the full width of the board. There are 15 vias placed directly under the IC, on and around its thermal pad, both to reduce ground impedance for better performance and to help conduct heat from the IC to the bottom side of the board where it can be effectively radiated away.

The 1nF and 220nF bypass capacitors are immediately adjacent to the IC, with the 1nF C0G types the closest, as they have the best high-frequency performance. The placement of the 100µF electrolytics is less critical. Note that there is provision to use 22µF 25V SMD multi-layer ceramic capacitors (1812 size) instead but the cheaper electros do the job well.

The IC's pin layout is well-optimised, with the main power supply and all output related pins on one side, which we have orientated towards the right side of the PCB. Thus the filter components are placed immediately between the IC and CON4/CON5 at right. The analog ground pin (pin 8) is on the left side of the IC and this is the only point at which the power ground meets the signal (analog) ground.

Construction

Fig.5 shows the assembly details. Apart from some of the components being relatively close together, the only tricky thing about building this board is soldering IC1 (a magnifying lamp will come in handy here).

We used hot-air reflow as this (or oven reflow) is best for ICs with thermal pads (like the TPA3113D2). The equipment is surprisingly cheap; we paid around $60 for an Atten 858D+ hot-air soldering station while hot-air reflow wands can be had for as little as $25. But you can do it with a regular soldering iron too.

For hot-air, the trick is to use a very thin layer of fresh solder paste (kept in the fridge!). Spread this sparingly on the pads, drop the IC on top, heat it (gently at first) until all the pins reflow and then for a few seconds longer and Bob's your uncle.

If all you have is a regular iron, apply some no-clean flux paste to the thermal pad on the board and also the pad on the bottom of the IC. Then melt a small amount of solder to both; just enough to tin them. Start with the PCB pad so you can get an idea of the correct amount. If you add too much, add a bit more flux and then remove the excess with some solder wick (harder to do with the IC!).

Having tinned both, place some fresh flux paste on all the IC pads on the PCB, including the thermal pad, then pop the IC down in place, checking its orientation. Next, move it slightly out of the way, tin one small corner pad and then slide the IC into place while heating that pad.

Now check that the IC lines up with all its pads. If it's misaligned, reheat and gently nudge it into place. Try to avoid getting solder on any other pads

Use a magnifying glass (or magnifying lamp) to check carefully that all the pins are sitting properly over their pads, then tack down the diagonally opposite pin. Re-check the alignment, then solder the rest of the pins, making sure not to disturb either of those first two solder joints.

Having soldered the pins, it will then be necessary to flip the board over

Left: the completed PCB assembly. Don't be intimidated by the SMD parts; they're quite easy to install if you follow the instructions in the text but you do need a good magnifying glass (or magnifing lamp), tweezers and a soldering iron with a small chisel tip.

and apply enough solder to the pad on the bottom to transfer heat through the vias. Heat this solder until the flux between the IC and board vapourises, indicating that the thermal pad has reflowed. This will take a good few seconds but don't overdo it as you could cook the chip.

Regardless of which method you used to solder the IC, check carefully for bridged pins (again, use a magnifying glass) and clean up any that look dodgy up with some flux paste and a clean piece of solder wick. The bridges should clear easily; press the wick down onto the board but not over the IC pins as they are small and easily damaged.

As a final measure, it's a good idea to clean the flux residue off the board using a specialised flux cleaner (or in a pinch, an alcohol or acetone) and then carefully check all the soldering, again with a magnifying glass. Check that all the bridges are gone and that the solder has flowed cleanly onto all the pins and pads.

Remaining parts

There are nine SOT-23 package transistors, diodes and zener diodes to solder. These are quite easy as the pins are well spaced but don't get the various device types mixed up. Start with Q1 and Q2, then solder D1 and D2 and finally the five identical zener diodes. The easiest method is to put a bit of solder on the central pad and slide the device into place while heating that pad. Then solder the other two pads (a dab of flux paste makes it easier) and refresh the first.

Now move onto the SMD passives, starting with the resistors and then the capacitors and ferrite beads. Use a similar method as for the SOT-23s. The main thing to check for with these parts is that the solder has flowed onto the pad and not just the end of the component. As before, adding flux smoothes solder flow.

Note that the resistors will have printed values on them but the capacitors and ferrite beads will not, so check the packaging before fitting them. Remember to fit either 0Ω resistor LK3 only (stereo mode) or LK1 and LK2 only (mono mode).

If using the SMD LEDs, they can

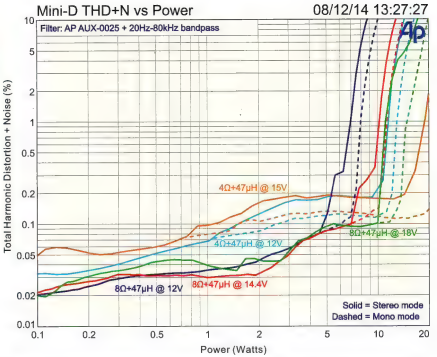


Fig.6: distortion versus power for a range of load impedances and supply voltages. Performance is generally better for 8Ω loads but power delivery is higher into 4Ω. Note the test load series inductance, to simulate loudspeakers.

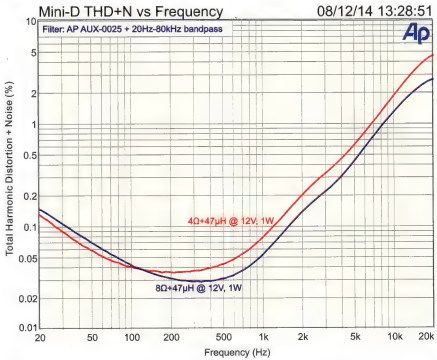


Fig.7: distortion versus frequency at 1W. As usual, the distortion rises with frequency but it also rises at the low end due to coupling capacitor-induced distortion. It's below 0.1% between 40Hz and about 1.5kHz.

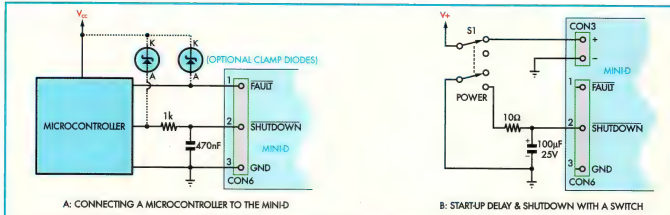


Fig.8(a): the shutdown pin (pin 2) of CON6 can be pulled low under no-signal conditions (eg, using a microcontroller) to reduce power consumption. The RC filter shown provides slew rate limiting, while external clamp diodes may also be required with some micros (see text). Fig.8(b) at right shows how to add a capacitor (eg, 100µF) to give a switch-on delay, while a DPDT power switch (S1) can be used to eliminate switch-off clicks or pops.

go in next but first you will have to check their polarity. Unfortunately, markings are inconsistent so use a DMM in diode test mode and try connecting the probes both ways around. When the LED lights, the red probe is to the anode and this goes towards the bottom of the PCB (marked with "A"). We used a green LED for LED1 and a red LED for LED2.

Through-hole components

That's it for the SMDs so once you're confident that they've all been soldered correctly, there are just a few through-hole parts left. If you aren't using an on-board volume control, solder wire links in place of VR2 and VR3 where shown. Also, if using off-board LEDs, fit 2-way pin headers CON7 and CON8 in place of the LEDs.

Next, move on to links LK4-LK6, CON6 and the inputs (if you aren't fitting RCA sockets). That done, dovetail two screw terminal blocks together and solder them in place for CON4 & CON5 (wire entry holes facing outwards). CON3 can then go in.

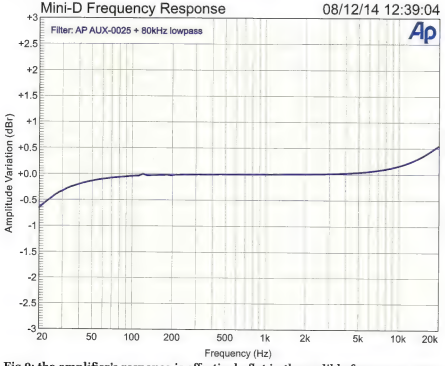


Fig.9: the amplifier's response is effectively flat in the audible frequency range. There is a low-frequency roll-off due to the high-pass filter formed by the input coupling capacitors and volume pot, while the rise at the high end can be attributed at least partially to the inductance of our test load.

If you are using onboard volume control pot VR1, fit it now (or trimpots VR2 & VR3). RCA sockets CON1 & CON2 can then go in, followed by the electrolytic capacitors (take care with their orientation).

Set-up & testing

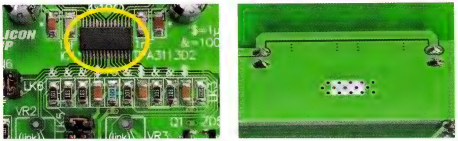
Initially, fit LK4 and LK5 (note that they go in vertically) and LK6. Turn the volume pot(s) to minimum, then apply DC power to CON3 (say, 12V) and measure the current. It should be just under 40mA (but possibly as high as 55mA) and LED1 should be on while LED2 should be off. If anything is wrong, switch off immediately and check for faults. Also double-check that you have connected the supply wires with the correct polarity.

Assuming that all is OK, switch off and connect a signal source such as a CD player, MP3 player, oscillator or mobile phone. Connect the speaker(s), then switch back on and slowly turn the volume up. It's now just a matter of making sure it sounds right. If you get to maximum volume and it's still too quiet, switch off and increase the gain by changing LK4 and/or LK5 but remember to turn the volume down before re-applying power.

Shutdown control

To reduce power consumption when power is applied but no signal is present, you can pull the shutdown input (pin 2 of CON6, pin 1 of IC1) low to enter a power-saving state. However, there are a couple of provisos.

First, the data sheet specifies that this pin should be slew rate limited to 10V/ms unless the source impedance



The TPA3113D2 IC (circled) should be installed first, following the procedure described in the text. The photo above right shows the corresponding heatsink area for this IC on the back of the PCB. It's connected to a thermal pad on the top of the board by 15 vias.

This larger-than-life-size view shows the heatsink pad on the underside of the TPA3113D2 Class-D audio amplifier IC.

is at least 100kΩ but it doesn't say why. Confusingly, they also show sample circuits where a "control system" (eg, a microcontroller) drives the shutdown pin via just a 1kΩ series resistor, which is unlikely to limit the slew rate to their specification.

We would be tempted to try that but not knowing the reason for the limitation, a safer approach would be to add an RC filter, as shown in Fig.8(a). The same comments apply if you're going to use a switch, relay, transistor or something else to pull down the shutdown pin.

If connecting a micro in this manner, note that the on-board pull-up resistor could pull its control pin above the micro's supply voltage. Normally, the microcontroller pin will have a clamp diode to its positive supply rail to limit the voltage on that pin to a safe level. However, some micros lack a positive clamp diode (eg, 5V-tolerant pins on a 3.3V micro) and in that case, you will need to add an external clamp diode (or a low-voltage zener to ground) to protect the micro – see Fig.8(a). The situation is the same if connecting the FAULT signal to a micro.

Powering up & down

We didn't hear any clicks or pops or run into other issues when powering the Mini-D up or down normally but there are a couple of issues noted in the data sheet which constructors should be aware of.

If the signal source is powered up at the same time as the Mini-D and there are large initial transients on those signals, that could trigger the DC offset protection in the Mini-D and once that's activated, its outputs will remain disabled until the power is switched off and on again. So in that case you need to hold shutdown low until the audio signals stabilise. This can be achieved with a capacitor between the shutdown pin and ground. A 22μF capacitor will give a switch-on delay of around 100-200ms, a 100μF 500-1000ms and so on. Or if a micro is connected to shutdown, it can do the same job.

The data sheet also states that pulling shutdown low before power is removed will minimise clicks or pops. While not strictly necessary, this can be achieved using a DPDT power switch; see Fig.8(b). This will bring shutdown low almost immediately while the supply capacitors take some time to discharge. SC

Another view of the completed PCB assembly. Links LK1-LK3 have been configured for stereo operation; ie, LK1 (0Ω) in, LK2 & LK3 out.

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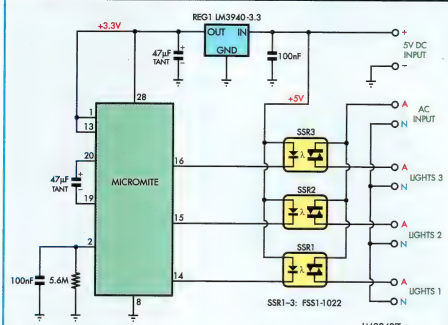
CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.



Micromite-based controller for 230VAC LED downlights

I have recently added a couple of LED downlights to my living area to improve the lighting when someone wants to read or work. Unfortunately though, these are far too dazzling for those for us who want to watch television. I did not want to go to the effort or expense of wiring in additional switches for each light but wanted to be able switch on any combination of lights.

This circuit is based on the Micromite (see May-August 2014 issues) and allows you to set any combination of lights using a single light switch which feeds power to the Micromite. The Micromite controls three solid-state relays (SSRs) and these provide the 230VAC switching of the downlights.

Power to the Micromite is supplied by a 5V mobile phone charger. They are readily available but avoid using cheap ones from China which do not have the required shrouding and sleeving of the two 230VAC pins. An LM3940 3-terminal regulator provides 3.3V for the Micromite.

When you apply power, only the lights that were last on will be switched on. If you turn the switch off, wait for around one second, then switch it back on again, it goes into program mode, which will then cycle through each combination, with a 3-second pause between each change. If you then turn it off, it will save the current setting in the Micromite's EEPROM and then use that setting whenever you turn it back on. It's necessary to wait for three seconds before turning it back on immediately after saving the new setting, to avoid triggering the program mode again.

Most of the hard work is done by the Micromite controller with a short BASIC program. The circuit includes a resistor/capacitor combination at pin 2 which is used to determine if the lights should come on normally or if the device starts in program mode.

When the program starts, it reads the voltage on the capacitor and if the voltage is 0.8V or higher (set in line 22), it goes into program mode. Once the voltage is read, it outputs 3.3V on pin 2 to charge the capacitor. When the power is switched off, the capacitor is discharged through the 5.6MΩ resistor.

The solid-state relays are switched by 5V-tolerant open-collector outputs on the Micromite. You can add more lights to the system by using other 5V-tolerant pins or using an external transistor on a normal digital output.

You can set the sequences for all the lights by entering values in the Data statements in lines 5-7 of the program and setting Num (line 4) to the number of values plus 1. Make sure the last values of each sequence are 0. This is used by the program to turn off all the loads when the EEPROM is written to. This minimises the load from the power supply, ensuring the program has plenty of time to write to EEPROM.

Suitable solid-state relays can be purchased from Jaycar (Cat. SY-4080) or Altronics (Cat. S-4410). Note that the load current to be switched must be less than the rating of the SSR. Note also that all mains wiring must be done to Australian/NZ standards.

Testing revealed a problem when using CFL lamps with the solid state relays, as they would flash occasionally. This can apparently occur with solid state relays but is not a problem with other types of lamps and can be fixed by having a normal incandescent lamp in parallel with the CFL.

The software, LEDSwitch.bas, is available on the SILICON CHIP website.

Dan Amos,
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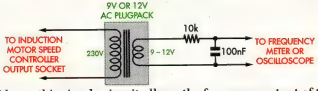
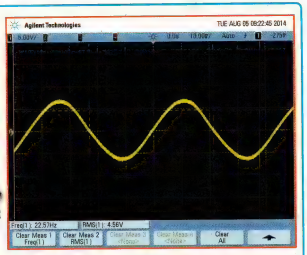
Measuring the frequency output of the Induction Motor Speed Controller



Above: this simple circuit allows the frequency output of the Induction Motor Speed Controller to be safely measured.



Right: this scope grab shows a 22Hz output waveform from the Speed Controller, as measured using the above circuit.

A number of readers have requested a simple method of reading the output frequency of the Induction Motor Speed Controller (SILICON CHIP, April, May and December 2012). This is needed as part of the initial set-up procedure. As it happens, there are two simple ways of doing this.

The first requires that the lid is removed so that you can access the ICSP socket adjacent to the microcontroller. Pin 15 of the microcontroller runs at half the output frequency, so that when the Speed Controller's output frequency is 50Hz, there is a 25Hz square wave at pin 15, with an amplitude of just slightly less than 3.3V.

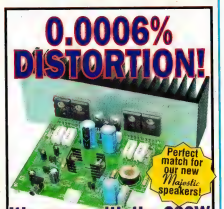
This can easily be measured with an oscilloscope, frequency meter (or DMM with frequency capability) between pins 5 & 3 of the ICSP socket. However, there is some hazard to using this method as the lid must be off and this exposes the high-voltage circuitry which could be a lethal hazard for an uninformed observer.

A somewhat easier and much safer method, which does not necessitate access inside the Induction Motor Speed Controller case, involves the use of a 9VAC or 12VAC plugpack plugged into the 230VAC output socket. Some digital multimeters will be able read the output frequency directly from the output of the AC plugpack while others may be unable to resolve the low-frequency signal, due to the high-amplitude, high-frequency PWM switching signal at around 16kHz and above, although this will be partially filtered by the AC plugpack.

In that case, a simple RC filter comprising a 10kΩ resistor and 100nF capacitor will will attenuate signals above 1kHz to enable an oscilloscope, frequency meter or DMM (with frequency capability) to easily measure the signal.

The accompanying scope grab shows the result when the Speed Controller is set for an output of 22Hz. This would give slightly less than half nominal speed for a induction motor, eg, around 720 RPM for a motor with a name-plate speed rating of 1440 RPM.

SILICON CHIP.



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An improved tweeter horn for the Majestic loudspeaker system

When we published the Majestic loudspeaker system in the June 2014 issue, it created a great deal of interest; more than even we had hoped for. We thought that readers might think it a huge throwback to the 1950s but evidently it has been a hit. So much so that the originally specified Etone tweeter horn has now become unavailable. Fortunately though, we have been able to source a Celestion horn which looks and sounds even better.

By Allan Linton-Smith & Leo Simpson

This photo shows the front and rear views of the Celestion T5134 diecast aluminium horn, together with the mating Celestion CDX1-1730 compression driver. Note the two rubber inserts in the horn on its longer axis. These evidently are for damping as the horn itself is quite 'dead'. Note also that only two mounting holes are provided for attaching the horn to the compression driver.

This photo shows two views of the assembled compression driver with the diecast aluminium horn. The horn has four holes for attaching it to the baffle and pan head screws should be used.

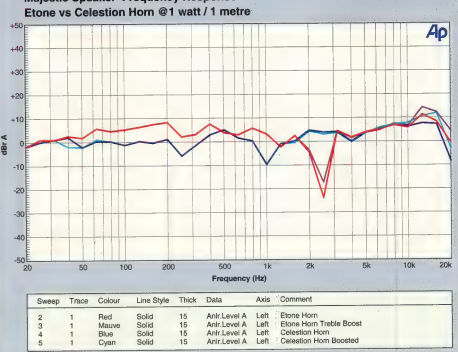


Fig.1: these four sweeps show the frequency response of the Etone and Celestion horns when fitted to the Celestion CDX1-1730 compression driver. As can be seen, the sweeps with the Celestion horn are smoother overall.

WE WERE PEEVED, to say the least, when the Etone tweeter horn used in the Majestic speaker system became unavailable shortly after the June issue went on sale. The news was even worse when Etone advised us that the Asian manufacturer of the horn had gone out of business.

We had to do some frantic searching to find a substitute horn which would perform at least as well as the Etone horn. Ultimately, we found that Celestion themselves had a suitable diecast aluminium horn which looked to be even better than the larger Celestion H1-9040P composite/plastic horn which we originally tried before rejecting it in favour of the Etone.

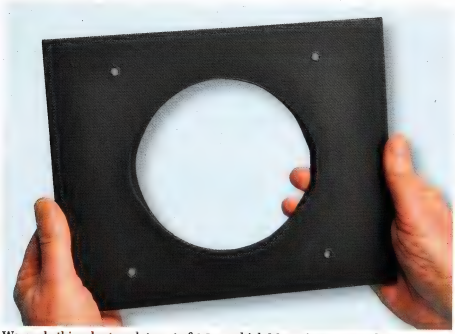
We then had to source the horns from Celestion in the UK and had to wait weeks before they arrived. Then they had to fitted to the Majestic enclosures and listening comparisons made between the Celestion and Etone horns. Our initial impressions were that the Celestion horns gave a smoother overall response and their vertical dispersion was somewhat better than the Etone unit. Then the whole system had to be precisely measured with a calibrated microphone etc.

Fortunately, our listening impressions were confirmed and the Celestion compression driver and horn combination is clearly superior. It would have been great if we had known about this horn right from the start!

Frequency & distortion

The Audio Precision graph in Fig.1 gives a comparison between the Majestic fitted with the now defunct Etone horn and the new Celestion horn. There are four frequency sweeps, numbered 2, 3, 4 & 5. Sweeps 2 & 3 are for the Etone horn, with sweep 3 showing the effect of the treble boost above 10kHz, produced by the peaking circuit in the crossover network.

Both sweeps produced a pronounced dip at 2.5kHz which is not audible but was caused by a standing wave



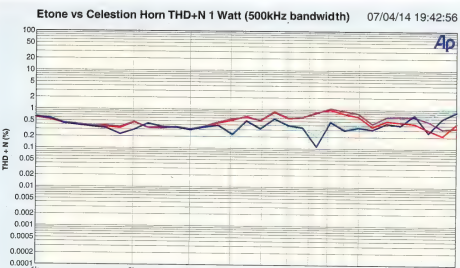
We made this adaptor plate out of 4.8mm thick Masonite to cover the large hole in the baffle for the Etone horn. We made the slightly elliptical cutout with a circle cutter set for a diameter of 130mm and then used a rasp to slightly chamfer both sides to suit the wider axes of the Celestion horn. It was finished with a matt epoxy-based paint to match the finish of the diecast horn.

from the floor reflecting into the test microphone. However, using exactly the same measuring set-up with the Celestion compression driver and aluminium horn gave no trough at this frequency. In this case, sweep 5 includes the boost above 10kHz while sweep 4 is without the boost. Overall, the Celestion horn had a much smoother response which was a confirmation of our initial listening tests.

More importantly, the harmonic distortion was also reduced, as shown in Fig.2. This shows harmonic distortion taken with a measurement bandwidth of 500kHz for both horns, over the range from 1kHz to 20kHz. Again, sweep 2 is for the Etone without treble boost and sweep 3 is with the boost. Sweep 4 is for the Celestion without treble boost and sweep 5 is with boost.

Overall, the Celestion compression driver/horn combination seldom exceeded 0.6% THD+N, even when boosted, whereas with the Etone horn it often exceeded 1%. Note that these THD figures are significantly higher than our original published sweeps which used an 80kHz measurement bandwidth. This tends to include a lot more harmonics and high-frequency noise but of course anything above 20kHz is simply not audible.

Incidentally, some readers have noted that the CDX1-1730 driver is only rated at 45 watts on the Celestion website but we have the actual printed specification sheet which clearly states that it is rated at 75 watts RMS (AES standard) which we believe is the correct rating.



Sweep	Trace	Colour	Line Style	Thick	Data	Axis	Comment
2	1	Red	Solid	15	Anlr.Level A	Left	Etone Horn
3	1	Mauve	Solid	15	Anlr.Level A	Left	Etone Horn Treble Boost
4	1	Blue	Solid	15	Anlr.Level A	Left	Celestion Horn
5	1	Cyan	Solid	15	Anlr.Level A	Left	Celestion Horn Boostad

Fig.2: these four sweeps show the THD performance of the Etone and Celestion horns when fitted to the Celestion driver. These figures have been taken with a 500kHz measurement bandwidth, resulting in higher overall figures than those shown in the June 2014 issue. Overall, the Celestion horn is the better performer.

Physical dimensions

As can be seen from the photos, the Celestion diecast aluminium horn has a smooth hyperbolic flare and an elliptical mouth, somewhat wider than it is higher, to give better horizontal dispersion. Even so, it also turns out to have improved vertical dispersion than the Etone horn and that means that the "sweet spot" for listening is somewhat higher – you don't have to be seated to get the best treble response; it is more widely dispersed.

The horn also has rubber inserts along its wider axis and we assume that these have been included to damp any resonances. Certainly the horn itself is quite "dead", with no tendency to ring.

The horn is attached to the Celestion CDX1-1730 compression driver using two 6BA x 20mm bolts, with a washer under each bolt head. These bolts are quite tricky to fit as they are little too long to be easily poked through the two mounting holes of the horn. To fit them, you need to slightly distort the rubber inserts, to temporarily provide clearance for the bolt heads. The bolts should not be over-tightened.

The new Celestion diecast aluminium horn is more compact than the Etone horn and will require a

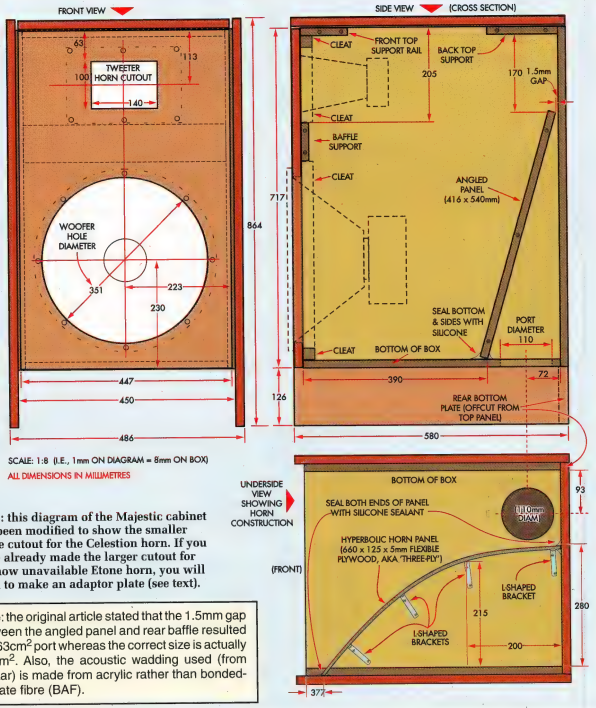


Fig.3: this diagram of the Majestic cabinet has been modified to show the smaller baffle cutout for the Celestion horn. If you have already made the larger cutout for the now unavailable Etone horn, you will need to make an adaptor plate (see text).

Note: the original article stated that the 1.5mm gap between the angled panel and rear baffle resulted in a 63cm^2 port whereas the correct size is actually 6.3cm^2. Also, the acoustic wadding used (from Jaycar) is made from acrylic rather than bonded-acetate fibre (BAF).

smaller cutout in the front baffle of the enclosure. The cutout can be in the form of a rectangle measuring 140mm wide by 100mm high. Fig.3 shows the dimensional diagram of the Majestic cabinet, amended with the smaller baffle hole for the Celestion horn. If you have already made the larger cutout for the Etone horn, you will need to make an adaptor plate because the new tweeter horn will not cover the larger hole. We made our adaptor plate from 4.8mm thick Masonite.

We made two Masonite adaptor plates, one for each enclosure. These plates each measure 255 x 205mm. Instead of cutting a rectangular hole in each for the horns we used a circle cutter set for a diameter of 130mm. We then used a circular rasp to chamfer both sides of the hole to allow the elliptical tweeter horn to sit squarely on it.

After lightly sanding it with very fine emery paper, we painted it with a matt-finish black epoxy-based paint which resulted in a finish quite similar to that on the Celestion horn. The horn requires four mounting screws and we used 8G x 25mm pan head stainless steel screws for this task although we would have preferred screws with a black oxide coating, to make them less obtrusive.

Finally, the Celestion T5134 "No-Bell" horn is available from Elfa (www.elfa.com.au) for $35 plus p&p (order code 28/H1-7050). The Celestion CDX1-1730 compression driver is also available from Elfa for $189.00. SC

Australia's Largest Radio Exhibition: The Canberra RadioFest

by KEVIN POULTER

Every few years, the Historical Radio Society of Australia (HRSA) displays a multitude of vintage radios and accessories, in a central location, for Australia's largest Radio Exhibition.

After a very successful event in Melbourne during 2012, Canberra is the host city for RadioFest 2014. If you'd like an unparalleled opportunity to view and purchase most radio-related items, then the HRSA RadioFest is for you. The venue is University House, in the ANU grounds, during the weekend of September 19 to 21.

A highlight this year is the members-only auction of the Rare, Early and Unusual, featuring masterpieces from the dawn of broadcast radio in the early 1920s. Superior to any previous Vintage Radio auction, there's never been anything quite like it.

Expect everything "top shelf": antique and unusual crystal sets, very early valve radios, spark gap transmitting coils, spectacular horn speakers. Full listings with photographs will be displayed on the HRSA website from mid-August: www.hrsa.asn.au

Saturday night's members dinner is an amazing opportunity to mix and chat with enthusiastic radio collectors and restorers from all around Australia and even some from overseas.

Great food and company is supported with the leading speaker, David Kilby from the ABC. Well-known for his Rare Collections program (Sunday nights 9.30pm) on Radio National, hear him at his funniest, most informal best.

Workshops are always popular too, demonstrating skills and techniques employed to resurrect silent, poor condition radios to make them look and work like new again.

Workshops include: Restoration with Stan Snyders (see **SILICON CHIP**, Feb. 2014, for a fine example of Stan's restoration), Mike Osborne showing a clever fix for dud early triodes in his session titled "1920s valves in the 21st century", plus "Safe Practice in Restoring

A rare ivory "marble" AWA Empire State radio.

For auction at RadioFest: An immaculate 1924 Atwater Kent Breadboard radio, complete with the original A-K horn, literature and superb craftsman-built glass display enclosure.

An extremely rare example of AWA's first commercial tunable radios, the 1925 Radiola 4 model.

A huge display of early telephones. Radio microphones were often similar the telephone mouthpieces.

Radios and phono items typical of the on display and for sale at the RadioFe

Vintage Radio Event: RadioFest

September 19-21, ANU University House, Canberra, ACT

Mains Radios", with experienced technician John Carr.

The Saturday afternoon is free to be a tourist and the best opportunity for members, wives and families to see Canberra's highlights on the free bus tour, or in your car. Spring in Canberra is beautiful featuring the Floriade flower display. Other often-visited attractions include the National Film and Sound Archive and the War Memorial. The free bus will also be available on Saturday night to ferry members from the preferred accommodation venues to the dinner and return.

Sunday's RadioFest sale and exhibition is open to all, with displays and a huge market of every conceivable radio, parts, books and ephemera. Collections on display include the magnificent output of Philips Radio at the height of its golden period, old telephones, early and intriguing transistor radios, plus much more. Society members will have access to the main trading hall early on the Sunday, from 8.30am. The hall is then open to the public from 9am to 3pm.

No doubt you've noticed there are members-only privileges throughout the weekend; however it's easy to become a member. The HRSA encourages people with an interest in vintage radio to join. At just $35 a year, including the quarterly colour magazine, access to circuits and 50,000 valves plus parts and so much more, like monthly meetings and regular auctions, the HRSA has to be the best value. Details on the HRSA website.

After the major display and sale, in the evening the HRSA's AGM will be held. The HRSA again acknowledges the contribution **Silicon Chip** magazine makes toward the conservation and promotion of Vintage Radio and their sponsorship of the event.

Further information on the Auction, Accommodation and Bookings is on the HRSA website **www.hrsa.asn.au** and the special event site: **www.ozradios.com**, or contact Richard Elliott, telephone (02) 4846 1096 for dinner and seller-stall bookings.

A range of early microphones, including a replica of the microphone used by Dame Nellie Melba in her first broadcast.

The winner of the best restored radio at the last RadioFest, an AWA C54.

Collectors love coloured radios and this green Astor in fine condition sold for $4,500 at the last RadioFest.

A display of batteries, essential for early valve radios.

Early and ornate loudspeakers. At the time speakers were external to the radio, not built-in.

Vintage Radio

By Ian Batty

Welcome To The Jet Age: Pye's Excellent C-2 Jetliner Transistor Radio

Pye's C-2 "Jetliner" meets all the obvious criteria for a successful portable radio. It's good-looking, has loads of audio output, picks up distant stations with ease, runs on almost-flat batteries and offers a tuning meter to precisely locate the "sweet spot". But it's what's under the hood that's really interesting.

AN ADDENDUM to the landmark 1960 "Mullard Reference Manual of Transistor Circuits" described a portable radio using the (then) new family of alloy-diffused transistors, the OC169/170. This design had a sensitivity of 20μV/m and considering that a ferrite rod antenna has a "loss" of some 10:1 (20dB in voltage terms), this implied a basic sensitivity of about 2μV.

At the time, the Mullard circuit demonstrated that transistor portables had developed to a point where they could compete with valve sets and win the contest. Very few valve radios could get anywhere near this figure without an RF amplifier stage.

Both the Bush TR82C Mk.2 and the Kriesler 41/47 (described in this column in September & December 2013) adopted the basic Mullard design. The TR82C, in particular, achieved outstanding sensitivity but suffered from excessive noise on its broadcast band.

As with the above two sets, Pye's Jetliner follows the iconic "Mullard Design". And like the 41-47, the Jetliner uses a PCB (the TR82C used a metal chassis and point-to-point wiring).

PCB construction often means restricted access to the circuit for servicing. Most sets, including the Jetliner, mount the board "component side" up, leaving the connecting tracks on the "inside" of the case. The Pye service data helpfully includes a component layout diagram. You can download the circuit and service details from Kevin Chant's excellent website at www.kevinchant.com

Circuit Description

Fig.1 shows the circuit details of the Pye Jetliner. Like the TR82C and 41-47, it follows the design that had become standard for the time: a self-oscillating mixer (TR1), two IF stages (TR2 & TR3), a diode demodulator and a transformer-coupled audio driver (TR4) feeding a push-pull transformer-coupled output stage (TR5 & TR6).

It uses six transistors (seven really), so it's the standard "trannie" that we all know. The transistors used in mine are Philips/Mullard germanium PNP types – alloy-diffused in the RF/IF section and alloyed-junction in the audio.

Bottom-coupled IF coils

Whoever put this circuit together threw away the conventional handbook when it came to designing the 455kHz IF strip. That's because it uses separate bottom-coupled IF coils in each stage (rather than conventional IF transformers).

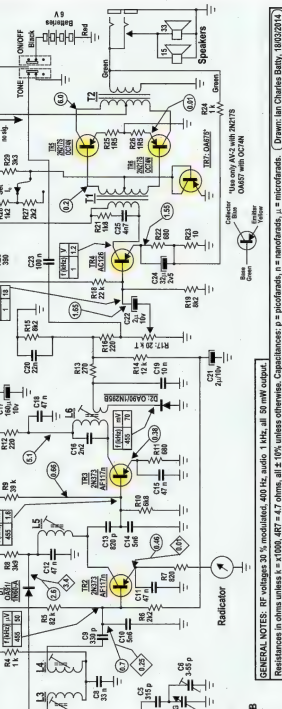


Fig.1: the Pye Jetliner's circuit uses a self-oscillator mixer (TR1), two IF stages (TR2 & TR3), a diode demodulator (D2), a transformer-coupled audio driver (TR4) and a push-pull transformer-coupled output stage (TR5 & TR6). D1 is connected to the mixer's output and provides AGC.

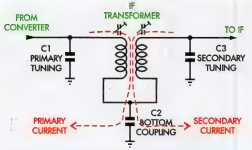


Fig.2: a bottom-coupled IF circuit. It uses two single-winding IF coils in separate cans and C2 couples the energy from the primary coil to the secondary coil.

Basically, a conventional IF transformer uses primary and secondary windings, both tuned to the IF (intermediate frequency). They are placed close enough so that their magnetic fields interact and couple energy from the primary to the secondary.

Their exact characteristics depend on the inductance of each winding and the spacing between them. It's possible to calculate the mutual inductance between them (ie, the degree of coupling), along with the primary-to-secondary voltage ratio and the total bandwidth.

However, while this method works well, calculations are laborious and transistor circuits require a low-impedance tapping on the tuned secondary for maximum power transfer.

A less intuitive (but simpler) connection uses bottom coupling. In this case, the two coils can be in separate metal cans and the calculations are greatly simplified. This design works just as well as the traditional "primary-plus-secondary" version but it does require two separate coil (and can) assemblies.

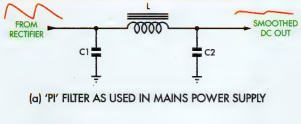
If you're familiar with valve circuits, top and bottom coupling may seem commonplace but this is the first time I've seen the technique used in a transistor set. It's a clever technique for several reasons. First, although it involves an extra coil can, each IF transformer has only a single slug that's adjusted from the top. So there's no need to get to both sides of the PCB for alignment adjustments, as would be the case with the conventional IF transformers.

Second, getting the exact degree of inductive coupling needed between two coils in the one can is an exacting piece of electrical and physical design. With bottom (or top) coupling, the coils are simply wound individually. The degree of coupling is then determined by a simple formula that specifies the coupling capacitor's value.

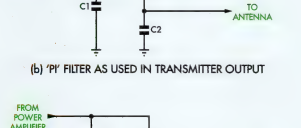
Finally, there's no confusion over correct slug positions: either of the two peaks is correct.

Coupling circuits

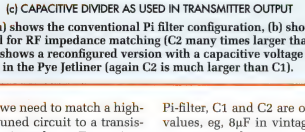
Before going further, let's digress and take a generalised look at coupling circuits, so that we can better understand how the Pye Jetliner's circuit works.



(a) 'PI' FILTER AS USED IN MAINS POWER SUPPLY



(b) 'PI' FILTER AS USED IN TRANSMITTER OUTPUT



(c) CAPACITIVE DIVIDER AS USED IN TRANSMITTER OUTPUT

Fig.3: (a) shows the conventional Pi filter configuration, (b) shows how it's used for RF impedance matching (C2 many times larger than C1) and (c) shows a reconfigured version with a capacitive voltage divider as used in the Pye Jetliner (again C2 is much larger than C1).

Basically, we need to match a high-impedance tuned circuit to a transistor's low input impedance. Transmitter circuits also need to match into low-impedance antenna feedlines, usually 50 ohms. As well, load impedances may be less than the feedline, requiring a step-up in impedance matching.

Although tapped coils can be used, it's easier to use some kind of capacitive voltage divider. This removes the "cut and try" method often needed at very high frequencies, where a coil may be only two or three turns and the exact tap location can be difficult to determine.

Most of us are familiar with the Pi-filter configuration that's used in mains-derived power supplies to smooth pulsating DC. What's not so obvious is that it can also be used in a tuned circuit to match impedances.

Fig.3(a) shows the conventional Pi-filter configuration, while Fig.3(b) shows how it can be for RF impedance matching. Finally, Fig.3(c) shows a reworked version with a capacitive voltage divider, as used in the Pye Jetliner.

In a conventional power supply Pi-filter, C1 and C2 are often of equal values, eg, 8µF in vintage radio sets. However, in the RF version (Fig.3(b)), C2 is usually several times larger than C1, so that C2's lower circuit impedance matches the antenna impedance. C1, on the other hand, provides a high-impedance load as required by the power amplifier's output stage.

Similarly, in the capacitive divider (Fig.3(c)), C2 is much larger in value than C1. The design calculations are simple and any desired impedance step-down is easily achieved.

The capacitive voltage divider has an additional bonus: in the Jetliner, the mixer's collector voltage is blocked by the "top" capacitor. As a result, the bias network can apply bias directly to the first IF stage, as this point is also isolated from DC ground by the "bottom" capacitor. So we achieve resonance, impedance matching and DC blocking with just three components and no coil tappings.

Back to the Jetliner circuit

Unlike most 'broadcast-only' transistor sets, the Jetliner uses a tuning gang with identical aerial and oscillator sections. In fact, it's quite unusual to see this in a Japanese-manufactured 'polyvaricon' that uses a sheet plastic dielectric rather than air-spacing.

As in its valve predecessors with identical tuning-gang sections, this means a that padder capacitor must be added to the oscillator provide tracking. This is the 315pF capacitor (C5) coupling the tuning gang to the top of the tuned oscillator coil (ie, just to the right of the 2N374/AF116n transistor – see Fig.1).

The mixer uses collector-emitter feedback, thereby reducing the amount of local oscillator radiation that's fed back out through the antenna rod. This design also includes an OA91 damping diode between the DC collector load of the first IF amplifier (2N373/AF117n) and the mixer's collector circuit. This diode considerably improves the performance of the AGC (automatic gain control) on strong signals.

The mixer's output (ie, from TR1's collector) feeds the untapped primary of the first IF transformer and it's here that some thoughtful design work becomes apparent. Conventional broadcast-band IF amplifiers use tappings on the IF transformers to match impedances, especially on the secondary winding. This is necessary to match the low base impedances of the IF amplifier transistors and the low impedance of the demodulator diode.

By contrast, in this circuit, the first IF transformer's secondary is tuned by C9 (330pF) and C10 (5.6n) connected in series (giving 310pF). Importantly, C10's low reactance provides a good match for the first IF transistor's base impedance.

But it's even more complicated than that! The original Pye circuit drawing depicts the first IF transformer as the usual "two coils in the one can" configuration, coupled by their mutual magnetic fields. In reality, L3 and L4 are individual inductors in separate coil cans. They are bottom-coupled via the 33nF capacitor (C8) that appears to be a simple bypass.

In reality, the IF signal circulating in L3's resonant circuit is fed through capacitor C8, raising one end above signal ground. The signal at this end is in turn coupled through to L4 to create a signal current in its resonant circuit.

The use of bottom coupling also explains the unusual connection of L4's 'cold' end. Why not just connect

it straight to ground? Because there would be no signal introduced into L4's tuned circuit; that's why.

Second IF stage

The second IF stage is simplicity itself. The signal from the first IF amplifier (2N373) is fed to a single tuned IF coil and then coupled via a capacitive divider into the base of the second IF transistor (also a 2N373). This divider circuit uses the same component count as a tapped-inductor version but is easier to manufacture because there are no coil tappings. There's also no need for a separate, low-impedance secondary winding on the IF coil to match into the second IF transistor's base.

The final IF transformer uses a tuned primary but also includes a low-impedance, untuned secondary to drive demodulator diode D2 (OA90).

The two IF amplifier transistors operate in a similar manner to the IF amplifiers used in most other sets. The first IF stage (TR2) operates with a collector current of about 0.5mA. This allows the AGC to reduce its collector current effectively, to lower the gain as required.

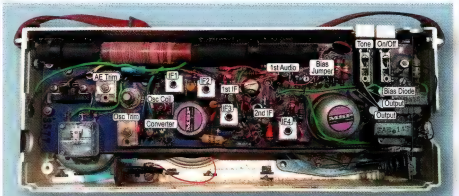
TR2's emitter is connected to ground via an 820Ω resistor and a small meter labelled "Radicator". This is a 500μA meter with a righthand zero and it functions as a signal-strength indicator.

With the set is turned off, the needle rests at the righthand end of its travel. Conversely, when the set is on and there is full emitter current through TR2 (ie, no station tuned), the needle swings fully left, indicating "no signal".

When a station is being tuned, TR2's emitter current falls due to AGC action and the meter swings to the right, towards the "maximum signal" position. In practice, it's just a matter of tuning the station for a maximum reading on the meter.

This signal-strength meter circuit is a common design and works equally well with both valve and transistor IF amplifier stages. Both types draw maximum current with no signal and minimum current with maximum signal. This is why these meters commonly indicate maximum signal strength when the power is off.

All the RF/IF transistors are AF-116/117 (or 2N374/2N373) alloy-diffused types. Their feedback capacitance is low enough that no neutralisation is needed at 455kHz.



This photo shows the component side of the PCB but note that the heatsinks for the output transistors and the bias diode (at right) have yet to be riveted together again following transistor replacement.

The demodulator (D2) is a conventional OA90 diode. The demodulated audio is fed via a voltage divider to the volume control, while the AGC voltage is derived via R14 and C21 and fed back to the bias network for the first IF amplifier (TR2). The diode's output is positive-going, so it "bucks" the negative bias applied to TR2's base, thereby reducing the transistor's collector current and lowering its gain. The stronger the signal, the greater the reduction in TR2's collector current and the greater the reduction in gain.

As with all AGC systems, the net effect is to keep the audio signal fairly constant with varying RF signal strengths. However, the amount of control we can apply to a single IF stage is limited; eventually the transistor will be almost completely cut off and there will be no further gain reduction.

It's not practical to control a self-oscillating mixer's collector current for AGC, as this would force the local oscillator off frequency. However, it is possible to apply damping to the primary of the first IF coil and thus reduce the converter's overall gain.

In the Pye Jetliner, that's done using the auxiliary AGC diode (D1). As shown in Fig.1, this diode (OA91/1N60-A) has its cathode connected to the DC supply for the first IF amplifier, while its anode connects directly to the mixer's output (ie, as fed to the first IF coil's primary).

With no AGC action (ie, little or no signal), the TR2's collector current pulls D1's cathode down to about 2.5V. This is about 2V more positive than its anode, so the diode is reverse biased and does not conduct. Conversely, as the AGC takes effect (and TR2 draws less current), the D1's cathode voltage rises, eventually becoming less positive than its anode. When that happens, D1 begins to conduct and this damps (or reduces) the signal at the converter's collector.

As a result, the mixer's output is effectively reduced and this significantly improves the overall AGC action.

According to Mullard, the AGC range improves from about 35dB (ie, input signal increase for a 6dB audio output increase) without the diode to over 55dB with the diode in circuit.

Audio stages

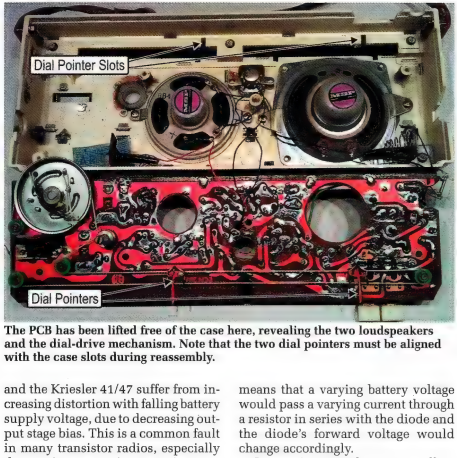
The audio driver stage (TR4) is biased in a similar manner to the IF amplifiers and works identically. However, it uses a larger emitter bypass capacitor and this is necessary to ensure that it is effective at audio frequencies.

TR4 drives the primary of transformer T1 which operates as a phase splitter. Its centre-tapped secondary drives a Class-B push-pull output stage based on transistors TR5 & TR6 and these in turn drive the centre-tapped primary winding of speaker transformer T2. T2's secondary then drives either two parallel-connected loudspeakers or a set of headphones via a headphone socket. Resistor R24 provides feedback from the output of transformer T2 to TR4's emitter to minimise distortion.

Note that the output stage dispenses with the usual voltage divider or voltage divider-plus-thermistor arrangement for thermal stability. Instead, a series resistor feeds a diode-connected transistor (TR7) and this reduces the bias applied to the output stage as the temperature rises. But that's not all it does, as we shall see.

A diode for bias?

Unfortunately, both the Bush TR82C



The PCB has been lifted free of the case here, revealing the two loudspeakers and the dial-drive mechanism. Note that the two dial pointers must be aligned with the case slots during reassembly.

and the Kriesler 41/47 suffer from increasing distortion with falling battery supply voltage, due to decreasing output stage bias. This is a common fault in many transistor radios, especially those using germanium transistors.

It's common to see a thermistor used in the output stage bias circuit but, in many cases, this only compensates for ambient temperature changes and cannot counteract falling bias with falling battery voltage. Worse, thermistors are often mounted on the circuit board and cannot compensate for overheating in an output stage that's being run at high volume. The Ferris M134 portable car radio was notorious for blown OC72 output transistors caused by just this problem.

In many sets, increasing crossover distortion as the batteries age can be so bad that owners will discard batteries before they are truly "flat". As a result, I've actually modified some of these sets for family and friends to improve performance.

Unlike the TR82C and the 41/47, the Jetliner uses a semiconductor "diode" in the bias network. Well, it's not really a diode. Instead, it's a diode-connected transistor (TR7), which has its base directly connected to its collector.

The reason for doing this is straightforward. In operation, a simple germanium diode begins to conduct at around 0.2V but its forward voltage rises quite rapidly with current. This means that a varying battery voltage would pass a varying current through a resistor in series with the diode and the diode's forward voltage would change accordingly.

Connecting TR7's base to its collector brings in transistor action. As soon as base current begins to flow, it will cause a larger collector current. This means that even a small increase in base voltage will cause a significant rise in total current, so the device acts as a diode with a sharper 'knee' than using the base-emitter junction alone.

This device not only delivers the required bias voltage but also has the same voltage-vs-temperature coefficient as the output transistors. As the temperature increases, the voltage across it reduces slightly to ensure that the correct bias is applied to the output transistors to ensure thermal stability.

As a result, the Jetliner (and sets with the same bias circuit design) deliver good audio performance until the batteries are almost dead flat. On test, the set easily delivered 50mW at under 10% distortion with "flat" batteries supplying just 3V, ie, half the nominated 6V supply voltage (4 x 1.5V cells).

The actual circuit specifies either of two bias transistors (AV-2 or OA675), depending on the actual output transistors used. The transistor is fitted with a "flag" heatsink that's riveted to those used for the two output transistors. This gives tight thermal coupling so that the transistor-connected diode will respond to output transistor temperature variations. Even the best thermistors, separately mounted flat on a circuit board, cannot match this degree of bias voltage response.

Transistor manufacturing tolerances mean that some form of bias adjustment is needed. As a result, the Jetliner provides a jumper to select one of two bias values. This jumper either places resistor R28 in parallel with R29 or a series combination of R28 & R27 in parallel with R29.

Finally, emitter resistors R25 & R26 provide some local feedback and help balance differing gains in the two output transistors.

Getting it going

As it came to me, the set was almost dead. A common problem with old transistor sets is no output at all due to corroded/tarnished contacts on headphone jacks and power switches. By contrast, this set worked but its performance was extremely weak.

What was strange was that the signal meter indicated a "strong signal", with the pointer stuck at the righthand end of its travel. That just had to be wrong but it was also a clue as to the fault.

It didn't take long to find the cause – a bad solder joint between resistor R7 and the meter. And since R7 is transistor TR2's emitter resistor, this upset the operation of the first IF amplifier stage.

Once this joint had been resoldered, the set leapt into action. However, I was unhappy with the performance of the output transistors, so I raided my junkbox and replaced them. I then tested the set and found that I was able to tune stations from one end of the broadcast band to the other. Considering my country location, it was a good result and the Pye Jetliner seemed to be a pretty sensitive set.

A note on circuit board removal and replacement: the two dial pointers sit in a channel moulding behind the dial inserts and cannot be removed unless they are set to the top end of the band, so that they align with a couple of slots in the case. Similarly, on replacement, the two pointers must be lined up with these slots, as shown on one of the photos.

A bit about noise figures

It was time to pop the set onto the test bench to find out just how sensi-

Freq (kHz)	Signal (uV/metre)		
1400	100	150	750
600	300	500	2500

This photo shows the needle positions on the 'Radicator' for various signal strengths at 1400kHz & 600kHz.

tive it really was and take a few noise measurements. Before doing that though, I applied contact cleaner to the switches and volume pot and then gave it a quick alignment check.

I measure sensitivity for a 20dB signal-to-noise ratio at 50mW output and at 30% modulation. To meet this 20dB requirement, I first set the input signal for 50mW output. I then turn the modulation off and (hopefully) get only 0.5mW of output. This gives me a S/N power ratio of 20dB.

If the noise-only signal is above 0.5mW, the volume control is turned down until the output reaches this level. I then turn the modulation back on and increase the input signal to get the 50mW standard output. In practice, it's common to juggle the volume control and signal generator output to get 50mW output at 20dB S/N ratio.

You may wonder why I don't simply detune the signal generator or turn it off, as this would give less noise. The reason is that the 20dB figure must be the "on signal" ratio, ie, the ratio of the audio output to the noise in the received signal.

How good is it?

The frequency response of this set from the volume control to the loudspeaker is 140Hz to 25kHz ±3 dB. So the high end is pretty "snappy" but a few more henries in the transformer windings would have given a better bottom end. Unfortunately, the IF channel (as in most broadcast-band AM radios) is the bottleneck. From antenna to speaker, the frequency response is 140Hz to about 2.8kHz, confirmed by an IF selectivity of -3dB at ±2.8 kHz. At 60dB down, the selectivity is about ±15kHz.

The audio performance is pretty good, with a total harmonic distortion of just 3.5% for a 1kHz signal at 10mW output. At 50mW output, the distortion is still just 4%. It rises to around 7% just as the amplifier begins to clip at 250mW output.

The transistor-diode's biasing superiority shows up with a low battery. At 3V (only 0.75V per cell), distortion is still only around 4.2% for 10mW output and is still under 5% at 50mW. Sets with resistor-biased output stages simply can't match this performance.

The Jetliner's RF sensitivity is outstanding and is under 3μV (ie, at the antenna terminal) for an output of 50mW. However, at this level, the signal-to-noise ratio is only 13dB at 1400kHz. The sensitivity falls to about 5.5μV if the gain is reduced to give the standard 20dB S/N ratio at this frequency. It's about the same at 600kHz, ie, 5μV for 50mW output at 20dB S/N ratio.

In operation, this set produces a 50mW output at a field strength of 20μV/m at 1400kHz and 55μV/m at 600kHz (both at full gain). The required field strength rises to 50μV/m at 1400kHz to deliver a 20dB S/N ratio though.

Where the Jetliner shines is in the IF channel. In fact, its sensitivity is four times better than the Kriesler 41/47's when taken at the input to the first IF stage – about 50μV compared to 200μV. Since both sets use the same transistors, it seems that the Jetliner's IF transformers and its improved coupling circuits are the secret.

AGC checks

Checking the AGC system revealed that the AGC control held the output to a 6dB rise for a signal increase of some 33dB. However, Mullard quoted 55dB with the specified AGC diode (D1), so what was going on?

Further checks showed that transistor TR2's collector voltage was only going to about 4V on full signal, during which the output was becoming distorted. Suspecting a fault in this stage, I tried shorting TR2's base to ground. This should have turned the transistor off and allowed its collector voltage to rise to at least 4.5V but this didn't happen.

Even with the set turned off, there was still some measurable resistance between TR2's collector and ground and the logical suspect was the .047μF (47nF) bypass capacitor (C12). This was one of those "red-tipped" high-value ceramics that's been notorious for leakage. On removal, it gave a resistance reading of about 10kΩ so it was effectively forming a voltage divider with the 3.9kΩ collector resistor (R8). And that in turn was preventing the AGC diode's cathode from rising high enough to obtain forward bias.

A new "greencap" capacitor fixed the problem. Shorting TR2's base to ground now resulted in its collector voltage rising to about 4.6V, as expected. More importantly, the AGC circuit was now working correctly with the set now handling a 60dB signal increase for an output power increase of just over 6dB (well in line with the original Mullard specification).

So leaky ceramic capacitors are a cause of trouble in low-voltage transistor radios. It's not just the electrolytic types that can cause problems.

Summary

The Jetliner is not a pocket set; instead its size and dual-speaker design make it a "picnic portable". Its sensitivity is one of its main features and the signal-strength indicator makes it possible to accurately tune stations.

It's a simpler set than the Bush TR82C and although the circuit is similar to that used in the Kriesler 41/47, its performance is much better.

In fact, its performance is excellent. It meets the manufacturer's impressive specifications for sensitivity and low-battery performance and my only reservation is the quoted output of 500mW, which I was unable to obtain. Some manufacturers do indicate up to 750mW output (with a 6V supply) for an OC74 push-pull output stage but the alternative 2N217 transistors appear to be lower-rated than the OC74s. It's possible that the 500mW figure quoted is for an OC74-equipped model.

Finally, note that the original circuit diagram for the Pye Jetliner shows TR7's base connected to its emitter. The base should in fact go to the collector (so that it correctly functions as a bias diode) and the circuit reproduced here has been corrected.

Further reading

If you've not already done so, take a look at Kevin Chant's excellent website at www.kevinchant.com It's a free resource for (mainly) Australian vintage radios and includes circuits, photos and parts information. SC

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Battery power for GPS Tracker

I am interested in building the GPS Tracker featured in the November 2013 issue of SILICON CHIP. We will be travelling to the UK later this year and hiring a car for part of our trip. At other times, we will be on taxis/buses/trains or walking, and we will not have access to a cigarette lighter socket. Is it possible to power the GPS Tracker from batteries (rechargeable or otherwise)?

Alternatively, could the unit run on 6V batteries and do away with the cigarette lighter socket totally? (D. W., via email).

● Yes, it would be possible to power it from nine AA cells but that is not very portable and the current drain of about 50mA would quickly flatten the battery. Because of how the power supply works you need at least 9V to power the device and it will not work properly with a 6V source.

GPS master clock wanted

Being a person with multiple clocks around the house I never really know the correct time as their drifts differ. Have you or would you design a master clock with a GPS module, that sends a signal to one or more slave clocks around the house, each slave clock having its own alarm setting function?

The alarm for each of the clocks could also have the ability to use an MP3 file or such. To expand on the slave clocks' ability to play an MP3 file, said clock could be set to play a file not only to wake you up but one also to send you to sleep, such as a slowly increasing sound of waves or white noise. (P. R., Bribie Island, Qld.)

● That sounds like a complicated project indeed. In fact, it would be simpler just to build one of our GPS clocks for each room where you really need an accurate time indication.

Of course, any mobile phone will also give you accurate time and if it is a smart phone it can provide white noise or whatever ambient sounds you want to send you to sleep.

CLASSiC-D amplifier transformer query

I have previously written to you regarding the modification of the Classic-D DC-DC Converter (SILICON CHIP, May 2013), to make it have an output of ±20V rather than the designed ±35V, so that I could use it to power the "Tiny Tim" stereo amplifier from the October 2013 issue. You advised that the secondary bifilar winding of T1 should have 15 turns rather than the originally specified 21 turns.

However, I foresee a problem in that, with the 21 turns, the bobbin well accommodates 7 turns across from S1 and S2, 7 turns back, and then 7 turns across again to terminate at pins F1 and F2. However, with 15 turns, there are only 5 turns on each pass, which doesn't fully cover the bobbin, there being gaps between the windings and therefore not a neat, compact three layers of windings. Would this affect the efficiency of the transformer?

I had thought that instead of having three layers of 5 turns, I could have one layer of 7 and one layer of 8 turns. This would bring the terminating wires back to the S1 and S2 position, but would it be then OK, after the primary winding of 7 turns is added on top of the secondary, to bring the end wires of the secondary winding straight over the top to the primary to terminate them on pins F1 and F2? (C. B., via email).

● Either way would be OK. The efficiency is not critical since you are not intending to draw the full power rating from the transformer.

For the first winding option, the gaps between windings are not important. With the second winding option with two layers, the final wire connection should run at right angles to the windings to terminate to F1 and F2.

Solar panels for hot water

With the dramatic drop in the price

Problem With MPPT Charge Controller

I have built the MPPT Charge Controller from the March 2012 issue but I am having difficulty in implementing this project. My input is 18V @ 4A, while the output is 13V @ 4A. So the input power is 72W while the output power is 52W.

Can you please help me to trace out the problem with this unit? (S. Y., via email).

● The voltage values you have for the MPPT charger input and output show that it is working as it is stepping down the voltage from 18V to 13V with the solar panel operating at its most efficient point which is usually around 18V for a 12V panel.

How the input power versus output power is measured and calculated is important for accurate results. Note that current is not continuous but with a switching component that is a significant proportion of the overall current. We suspect that the true output current from your MPPT Charge Controller is over 4A.

Your current measurement will need to be an RMS reading rather than an average current. A true RMS reading current meter will be required that is accurate for high crest factors and able to measure RMS values at 32kHz. There is no digital multimeter that will do this job.

You really need to use a digital oscilloscope which can provide RMS values for the current being monitored through low resistance shunts.

24V Speed Controller Needs Fast Recovery Diodes

I have an enquiry regarding the 24V/20A Speed Controller described in the June 1997 issue. Over the last 15 or so years, I have purchased three of these kits. Two have ultimately failed but overall they have performed quite well considering the conditions they operate under, ie, on a portable sawmill which is normally left out in the bush all the time.

Regarding diodes D1 & D2, it would appear as if I have replaced these with a 35A bridge rectifier at some stage. How I worked this out I do not know. But is this modification OK or is it better to stick to the original design? The motor load is 11A.

I would like to be able to find exactly what has failed on the other two boards. The first is obvious, as the two Mosfets are well cooked. On the second board, I fitted large heatsinks to the Mosfets and I cannot see any obvious failure. The voltage readings are not to specification but the "Testing" section of the text does not explain what to do if the readings are incorrect.

How would I test the Mosfets? I am getting quite a collection of them and I would like to know which are serviceable. By the way, I think that "C2" on page 30, second last paragraph should read "C3". (B. W., via email).

● The diode across the motor (D2) should not be a standard bridge rectifier. You need a fast rectifier such as an MUR1515 or MBR20100CT (Jaycar ZR1054). That substitution could be the cause of the Mosfets being damaged.

Note that better Mosfets have become available since we published the June 1997 controller. The IRF-1405N (Jaycar ZT2468) is higher rated than the original BUK456-60A and is rated for automotive use.

The Mosfets can be tested for a short circuit (low ohms) between drain and source with the power off. This resistance as measured on a multimeter should be high (meg-ohms) rather than close to 0Ω.

C2 is the 10µF soft-start capacitor at pin 4 of IC1. C3 is the 220nF (0.22µF) capacitor across the motor.

If the voltages are not correct when measuring as detailed in the testing section, IC1 is possibly faulty or you have a faulty resistor.

Finally, note that an improved version of this 12/24V Motor Speed Controller was published in the June 2011 issue and is sold as a kit by Jaycar (Cat. KC5502).

of solar panels, it is now becoming feasible to use power directly from a bank of solar panels to heat water using an electric hot-water service. Certainly, such a system overcomes many of the problems of traditional solar hot-water systems – running water pipes to the roof, freezing and boiling of the water, supporting the weight etc.

However, the element in a standard electric hot-water service is designed to run on 230VAC and so is not a good match to the variable output from a bank of solar panels. This is a long shot but would it be possible to adapt the MPPT Solar Charge Controller to efficiently couple the output from a solar panel bank into the resistive element in an electric hot-water service? (D. S., via email).

● We have touched on this topic previously and the idea does have some serious drawbacks.

A typical hot-water heating element requires far more current and voltage than the MPPT Solar Charger could deliver. It requires several kilowatts at 230VAC compared with 120W at 18V from the MPPT solar charger. In addition, providing DC to the heating element could accelerate corrosion.

If you were to use solar panels, the better option would be to series sufficient panels so that each panel provides 18V (assuming a 12V panel) at full sun for a total of 230V. The panels would need to be chosen to match the heater element current. A suitable DPDT heavy-duty relay could be used to switch element polarity each day or so.

433MHz sniffer project has no signal indication

I built the 433MHz sniffer described in the January 2011 issue but I have found that the ZW-3102 module supplied by Jaycar Electronics differs from the one in the article, as it now uses the Spirit-on Enterprises PT-4302 chip rather than the RX-3400.

While the modules seem to be otherwise similar, the PT-4302 chip lacks a peak signal output (RSSI tap in the article) so that a signal strength indication is not obviously possible. Can you suggest a workaround for this problem? (I. M., Mt Waverley, Vic).

● Unfortunately, the newer 433MHz modules do not have the 'hidden' Received Signal Strength Indication (RSSI) due to use of a different circuit. There's no easy solution to this so that while the piezo will still function, the LED signal indicator will not work.

Battery Lifesaver design query

I was interested in the Battery Lifesaver circuit as published in the September 2013 issue. On page 66 about half way down the third column, it is stated that ". . . The other half of D1/D2 clamps input pin 3 of IC1 to the 5V supply if the battery voltage is particularly high".

The cathode of the double diode (BAT54c) is connected to the input of the 5V LDO regulator which would be at the battery voltage or the battery voltage minus ZD1 if fitted and not to 5V as in the above statement. Is it a mistake in the schematic or an oversight in the design? (L. S., via email).

● That was a mistake in the design but the series resistor from the battery positive to pin 3 of IC1 limits the current flowing through its clamp diode in that situation anyway, so it shouldn't be a problem.

We tested the circuit to the maximum specified battery voltage and we haven't had any reports of failures.

CLASSiC-D amplifier module overheats

I recently built two CLASSiC-D Amplifier kits (Silicon Chip, November & December 2012), which I purchased from Jaycar. While one unit works perfectly the other one has a strange fault in which Q1 and Q2 both get very hot without any input signal or with the input shorted to ground. Q1 and Q2 will cool down immediately

Ultrasonic Cleaner Not Causing Cavitation

I purchased an Ultrasonic Cleaner kit from an Altronics store in Clayton, Melbourne. After constructing the kit I have not been able to achieve cavitation from the transducer.

Everything seems to work fine; it seems to be able to do both sweeping frequencies and higher frequency functions, both LEDs light up accordingly and it sounds like it should judging from the video on YouTube etc. It just doesn't seem to be getting enough power.

There is a staff member at Altronics who has had experience with this particular kit and he told me to solder the 10kΩ resistors over the zener diodes (which I missed) and to use a proper potting compound for setting the transducer in the pipe (as previously it was set in silicone caulk as per the instructions).

I've made those adjustments however I just can't get cavitation. I've included videos of both frequency modes and a picture of the circuit. What could possibly be wrong? (J. F., via email).

● Correct operation of the Ultrasonic Cleaner is reliant on the power supply being able to deliver sufficient current. You need a supply that can deliver at least 2.5A at 12V. The 4700µF capacitors deliver much of the peak current to the transformer but the supply needs to be able to deliver current to maintain charge on the capacitors.

One common problem with constructors of this kit is with the fuse clips. Check that the end stops on the clips are positioned on the outside so that they don't prevent the fuse from being inserted correctly. Make sure also that the clips grip the fuse tightly to ensure good contact.

when the Protect link is shorted.

I have replaced Q1 and Q2 but it made no difference. All checks and balances test OK. I'm currently stumped as to what it could be since the unit will still operate with this condition, with the only problem being that it will shut down after about 10 minutes due to over-temperature. Any advice? (B. W., via email).

● Check the 15V supply (Vcc), measured with respect to B-, and the V_B to V_S voltage (also 15V). This may be the problem if the gate drive voltage is well below 15V. If it is low, check resistor R9 and zener diode ZD1.

Alternatively, the dead time resistors may have incorrect values. Check the 5.6kΩ and 4.7kΩ resistors at pin 9 of IC1.

Tiny Tim is smoking resistors

I have built the Tin Tim amplifier (Silicon Chip, October & December 2013, January 2014) and the two 47Ω resistors are smoking and burnt out. Do you know what the cause could be? (Y. H., via email).

● You possibly have a short from the -20V lines to the early stages of the amplifier. The most likely cause is either a short between tracks on the PCB or diodes D12 & D14 have been installed the wrong way around. If the diodes have been reversed, install them correctly and replace the 47Ω resistors. The chances are that it will then work OK.

Balance control needed for old amplifier

I recently encountered problems with the volume and balance pots while trying to resurrect my Studio Twin-50 Stereo Amplifier (Silicon Chip, March & April 1992) that I built some years ago. A replacement volume control was obtained from Jaycar but the balance pot has proven difficult to obtain.

Are these 10kΩ MN pots still available or is there a workaround for this potentiometer? (D. W., via email).

● If you do a Google search for "MN dual gang potentiometer" you will find that there are a number of overseas sources for this type of potentiometer. However, getting an exact match for the dual-gang 10kΩ pot in your amplifier may be quite difficult.

Have you tried a squirt of Servisol contact cleaner (Jaycar NA1012) into the pot? Alternatively, you could try replacing it with a dual-gang linear 10kΩ pot. It will not be quite as good as the MN pot and it might not be mechanically centred to obtain equal gain in both channels but it will work.

However, the simplest way is to just bypass it, since you will probably never use it anyway. We have not included a balance control in any stereo amplifier or preamplifier we have published since the Twin-50 design.

Speed control for a shunt-wound motor

Regarding your 'Speed Controller For Universal Motors' in the February & March 2014 issues, I am considering purchasing one of these kits to power a DC shunt motor (not a universal motor).

At present, this motor is driving a metal lathe and the present speed control causes an unsatisfactory cutting tool feed, particularly at low speeds. This of course does not lead to a good surface finish. I think that much improved control could be obtained by connecting rectified and smoothed DC to the motor field and connecting your speed controller only to the armature.

I would consider that with a constant DC field and your PWM control, the motor would run much more smoothly with a narrow pulse width. I would appreciate your thoughts on this application . (G. M., via email).

● A shunt motor with constant DC to the field winding can be regarded as being similar to a permanent magnet motor. So to connect it for speed control, you should have a constant DC supply fed to the field windings while a PWM supply varies the voltage fed to the armature connections (via the brushes and commutator). It should work very smoothly.

The DC supply can be obtained using a suitably-rated bridge rectifier (same as BR1 in the PWM circuit) but no filtering is required and nor should it be used as it would result in a DC supply of over 320V – too high for the field windings. With a rectified but unsmoothed supply, the field current should be close to the value normally applied to the field.

Simple projects needed

I think that some of the recent Silicon Chip projects have been a little too elaborate and expensive. More simple projects are needed. I have ideas for two projects:

Firstly, how about a video pattern

Massive Battery Charger For Camper Van

I am a grey nomad who prefers being off-grid and as green as possible. I abhor those campers who run a generator 15 hours or more a day to charge their house batteries. The incessant drone is enough to drive one to drink excessively or worse.

Most generator battery charger circuits are 11A DC at most, so running a 3kVA generator to use less than 10% of its capacity, at an insufficient charge rate to restore full charge, means it is an exercise in futility. Their $20/day+ generator running costs means it would be better all round if they stayed connected to the grid.

Barring 'nuking' them, which may also damage my equipment, a high-power laser or electromagnetic pulse gun would be on my wish list of SILICON CHIP 'must have' projects. In the meantime, my wish to remain off-grid was recently thwarted by more than a week of inclement weather.

Being 'plugged in' at Cann River Caravan Park provided my 2 x 200Ah, deep cycle, flooded cell, 12V lead-acid, normally solar-charged house batteries, a much needed recharge at a maximum of 35A.

However, the ability to employ my unused 3kVA generator to quickly bulk charge my batteries means a rugged battery charger would be nice (see article in SILICON CHIP, April 2013).

eBay had 50 matching 11.5V 4A iron-core halogen downlight transformers with 45°C thermal cut-out at $1 each. However, the pickup in Melbourne only yielded 21 for $20. So I now have questions regarding my proposed 14.4V 100A rugged battery charger.

Is my proposed charger specification achievable? With one of the transformers connected as an auto-transformer to increase the primary voltage to the other 20 transformers as per page 91 of May 2013 issue? With four 35A 400V bridge rectifiers all paralleled and heatsinked and with fan cooling?

If I build a second charger and connect both in parallel, would the charge rate be the sum of both or would one charger take the bulk of the load as might an individual mismatched transformer? What would be the maximum current I could safely pump into such batteries? (T. H., via email).

● We have some misgivings about your proposed charger, using so many halogen lamp transformers in parallel. It will be a brute to wire up, will be very bulky and heavy and will get quite hot, since these transformers are not very efficient. You will need to use heavy-duty wiring and battery cables to suit the high current output. And you will definitely need a fan for cooling.

You will need to monitor the batteries quite closely because there is a major risk of over-charging if the set-up is left unattended for more than a couple of hours. You will need to check with the battery manufacturer to determine the maximum recommended charging rate.

generator that will generate a series of test patterns and blank coloured screens? While this type of project has featured previously, with the new video standards lately, it might be time for a new version. In order to be versatile, the pattern generator would need to have outputs for AV, VGA, DVI and HDMI and be capable of generating 4:3, 16:10 and 16:9 patterns. This might be a big ask but this device could be used for testing just about every video device ever invented.

The other thing I would like to see is a reasonably simple PCB layout without the use of microscopic, multi-legged SMDs. Keeping the construction simple would make the project more suitable for a wider range of readers with varying skills.

The second project I'm thinking of would be a sine/square wave generator with varying frequency outputs. There have been several projects of this nature over the years but many had very limited ranges. Such a device would have a wide variety of uses, from testing audio circuits to testing CRTs. (B. P., via email).

● Neither of those projects could be regarded as simple, particularly not the video pattern generator with your stipulation of HDMI, DVI, VGA etc. Commercial equivalents are very expensive. Apart from that, there is really not much need for such a device. After all, any PC can do the same job.

Similarly, you can easily obtain a

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WARNING!

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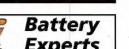

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Ask SILICON CHIP

. . . continued from page 101

sinewave generator which will work with your computer's sound card. Just do a Google search.

Ultra-low-power LED driver wanted

I need to drive a LED from a very low power source (1-1.2V with 200µA). I'm less than a beginner at this stage and have built a 'Joule Thief' which won't run that low. I have read about a Mosfet-based one that may do it and charge pumps etc (but they are such small chips and it looks very difficult to solder them without a microscope). Do you know of any circuits you could point me towards? (G. A., via email).

● It depends on what you want from the LED. If you are saying that you only have a 1.2V supply and only want to draw 200µA, then the LED will not show much past a very dim glow. That is after the voltage is stepped up to sufficient voltage to drive the LED. Typically, indicator LEDs are barely visible at currents below 1mA. A Joule Thief will not be able to supply any more power than is available from the supply.

If you want the LED to flash, then that might be achievable since the overall current will be low but LED current will be higher during the flash

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LED Causes Car Computer False Alarm

I'm hoping you can help me with a small problem I have. I recently had installed an after-market radio in my BMW X5 and this included a rear-view camera. The camera replaces one of the number-plate lights and has a LED for lighting the number plate.

The problem is that because of the lower power consumption of the LED, the car computer thinks the number-plate light is blown and constantly brings up a warning of "check number plate light" on the dashboard.

I'm guessing I would need to put a resistor either in series or parallel with the LED to get the car computer to stop nagging me. Can you suggest a suitable resistor value and should it be wired in series or parallel? (B. A., Margate, Tas).

- A 100Ω 5W resistor should be suitable and should be wired across the original number plate light connection (not across the camera LED). Presumably this would also be the power connection for the camera. What's probably happening is that the current drawn by the camera that includes the LED is insufficient for the car computer to accept that the bulb is not blown.

If a 100Ω 5W resistor doesn't solve the problem, use a 47Ω 10W resistor. The resistor should be mounted so that its heat can be dissipated without burning any plastic parts. Mounting it in a small diecast box would be best and you should ensure that the leads are insulated from the case.

The resistor should be secured against the box to heatsink it. Some heat resistant epoxy such as JB Weld can be used to affix it to the case or you could attach it using suitable brackets.

period. An LM3909 can flash a LED while drawing low current. You can purchase the IC and get a data sheet from www.futurlec.com/Linear/LM3909Npr.shtml

BFO wanted for shortwave listening

Did SILICON CHIP or "Electronics Australia" ever do a project for an external BFO to use with a shortwave receiver? This would resolve amateur SSB transmissions for listeners.

A useful addition to your web page would be the ability to search for projects, using supplied keywords. Of course, someone has to index the lot. (D. H., via email).

- We have a very comprehensive search facility on our website. Just go to the home page, hover over "Articles" and you will get a choice of searches: contents, word etc.

If you type "BFO" into the word search you will get nine results at www.siliconchip.com.au/Articles/WordSearch and the relevant one is at November 2010 at www.siliconchip.com.au/Issue/2010/November/High-performance+shortwave+converter

This takes you to a preview of the November 2010 issue. The relevant item is in the Circuit Notebook pages of that issue under the title "High Performance Shortwave Converter". This is suitable for AM and SSB reception from 6MHz to 17MHz.

Note that to access this article, you need to buy the full issue. SC

Notes & Errata

Playing USB-Stick & SD/MMC Card Music Without a PC, January 2012: on page 86, the article states that the Tenda TD896 requires two 2-pin JST leads for the audio outputs and a 3-pin JST lead for the earphone/speaker outputs. However, the two 2-pin JST headers/leads are for the earphone/speaker outputs while the 3-pin header/lead is for the audio (line level) outputs.

40V Switchmode/Linear Bench Supply, April-June 2014: the parts list swaps the part numbers for Q6 and Q7. Q6 is the BC327 and Q7 is the BC337. This is shown correctly on the circuit and parts layout diagrams and on the PCBs we supply.

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